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2009 Report

Water Quality Conditions in the Missouri River Mainstem System

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September 2010

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EXECUTIVE SUMMARY

Omaha District Water Quality Management Program

The Omaha District (District) of the U.S. Army Corps of Engineers (Corps) is implementing a Water Quality Management Program (WQMP) as part of the operation and maintenance activities associated with managing the Corps' civil works projects in the District. The WQMP addresses surface water quality management issues and adheres to the guidance and requirements specified in the Corps' Engineering Regulation – ER 1110-2-8154, "Water Quality and Environmental Management for Corps Civil Works Projects" (USACE, 1995).

A periodic report of water quality conditions in the Missouri River Mainstem System (Mainstem System) is currently being prepared annually to document and assess water quality conditions occurring at the Corps' Mainstem System projects in the District. The report describes existing water quality conditions and identifies any evident surface water quality management concerns. The annual reporting of Mainstem System project water quality conditions is done to facilitate water quality management decisions regarding the operation and regulation of the Mainstem System projects.

General Water Quality Concerns in the Omaha District

The following general water quality concerns have been identified for civil works projects in the District: 1) reservoir eutrophication and hypolimnetic dissolved oxygen depletion, 2) sedimentation, 3) shoreline erosion, 4) bioaccumulation of contaminants in aquatic organisms, 5) occurrence of pesticides, and 6) urbanization.

Prioritization of District-Wide Water Quality Management Issues

The District has identified eight priority issues for water quality management; these priority issues and their relative ranking are listed in Table 1-2.

Summary of Project-Specific TMDL Considerations, Fish Consumption Advisories, and Other Water Quality Management Issues

Table 1-3 summarizes TMDL considerations, fish consumption advisories, and other water quality management issues applicable to the Mainstem System projects. The impaired uses and pollutant/stressors (i.e., TMDL considerations) and identified contamination (i.e., Fish Consumption Advisories) identified in Table 1-3 are taken directly from the latest State 303(d) impaired waters listings and issued fish consumption advisories. They are provided for information purposes and are not based on water quality monitoring conducted by the District. The listed other water quality management issues in Table 1-3 were identified by the District based on water quality monitoring and Corps water quality management concerns. Water quality management issues at specific Mainstem System projects will be assessed in further detail in Project Specific Reports (USACE, 2010a) that will be prepared for the project by the District.

Limnological Processes in Reservoirs

The Mainstem System projects in the District involve the operation and maintenance of reservoirs and the regulation of flows discharged from the reservoirs. Much of the water quality monitoring conducted by the District is done to determine existing water quality conditions and identify water quality

management concerns at these reservoirs. A basic understanding of the limnological processes that occur in reservoirs is needed to interpret the water quality information provided in this report. Chapter 2 of this report provides a basic overview of limnological processes that occur in reservoirs.

Water Quality Monitoring at the Mainstem System Reservoirs

Long-term, fixed-station ambient water quality monitoring has occurred at the six Mainstem System reservoirs (i.e., Fort Peck, Garrison, Oahe, Big Bend, Fort Randall, and Gavins Point) for the past 30 years. Recent ambient monitoring conducted by the District at the Mainstem System reservoirs included monthly (i.e., May through September) water quality monitoring at a near-dam, deepwater site. At Garrison, Fort Peck, Oahe, and Fort Randall Reservoirs, additional long-term ambient sites were respectively added in 2006, 2007, 2008, and 2009. Water quality monitoring included field measurements and collection of depth-discrete water samples for laboratory analysis.

The District has monitored bacteria levels present at swimming beaches at the Gavins Point Project over the past 5 years. Five swimming beaches on Lewis and Clark Lake and one on Lake Yankton were monitored. Weekly grab samples were collected from May through September and analyzed for fecal coliform and *E. coli* bacteria.

Intensive water-quality surveys have recently been completed or are ongoing at all the Mainstem System projects. A 3-year intensive water-quality survey was completed at the Garrison Project in 2005, the Fort Peck Project in 2006, the Oahe Project in 2007, and the Fort Randall Project in 2008. Intensive water-quality surveys are currently ongoing at the Big Bend and Gavins Point Projects. The monitoring objectives of the intensive surveys are to collect water quality data to spatially describe water quality conditions present in the reservoirs during the late spring and summer, and to collect information to facilitate the application of the CE-QUAL-W2 hydrodynamic and water quality model.

Water Quality Monitoring at the Mainstem System Powerplants

As part of the operation of the Mainstem System powerplants, water is drawn from the intake structure of each dam and piped through the powerplant in a "raw water" supply line that is tapped for various uses. The "raw water" supply line is an open ended, flow-through system (i.e., water is continually discharged). A monitoring station, that measures water quality conditions of water drawn from near the start of the "raw water" supply line, has been irregularly maintained at each of the powerplants over the past several years. Recent water quality monitoring has consisted of year-round, hourly measurements of temperature, dissolved oxygen, and conductivity through the use of a data-logger. Monthly grab samples (year-round) have also been collected and analyzed. The water quality conditions measured in the "raw water" supply lines of the powerplants are believed to represent the water quality conditions present in the reservoirs near the dam intakes and in the tailwaters (i.e., Missouri River) immediately downstream of the dam.

Water Quality Monitoring of the Missouri River from Fort Randall Dam to Rulo, Nebraska

Since 2003, the District has cooperated with the Nebraska Department of Environmental Quality to monitor ambient water quality conditions along the Missouri River from Fort Randall Dam to Rulo, NE. Fixed-station monitoring has occurred at the following ten sites: Fort Randall Dam tailwaters; near Verdel, NE; near Niobrara, NE, Gavins Point Dam tailwaters; near Maskell, NE; near Ponca, NE; at Decatur, NE; at Omaha, NE; at Nebraska City, NE; and at Rulo, NE. Water quality monitoring consisted of taking field measurements and collecting near-surface grab samples monthly year-round. The collected grab samples were analyzed for various parameters. A 3-year water-quality intensive survey of

the Missouri River from Gavins Point Dam downstream to St. Louis Missouri will be jointly implemented with the Kansas City District beginning in 2010.

Water Quality Monitoring at the Mainstem System Ancillary Lakes

Lake Yankton, Lake Pocasse, and Lake Audubon are ancillary lakes to the Mainstem System reservoirs respectively at the Gavins Point, Oahe, and Garrison Projects. Water quality monitoring at these three lakes has been irregular in the past. The District initiated ambient water quality monitoring at the lakes in 2006 as part of a 3-year rotational monitoring cycle. These lakes were monitored in 2009. Monitoring included monthly sampling (May through September) at a near-dam deepwater location and included field measurements for depth profiling and water transparency and collection of near-surface and near-bottom water samples for laboratory analysis.

Water Quality Assessment Methods

For the purposes of this report, existing water quality is defined as water quality conditions that occurred during the past 5 years (i.e., 2005 through 2009). Water quality monitoring conducted during that period was used to describe existing water quality conditions.

Statistical analyses were performed on the water quality monitoring data collected at the Mainstem System reservoirs (including inflow and outflow sites), powerplants, on the Missouri River, and at the mainstem ancillary lakes. Descriptive statistics were calculated to describe central tendencies and the range of observations in existing water quality. Monitoring results were compared to applicable water quality standards criteria established by the appropriate States pursuant to the Federal Clean Water Act.

Longitudinal contour plots were constructed when adequate depth-profile measurements were collected along the length of a reservoir. Adequate information was collected in 2009 to construct longitudinal contour plots at all of the Mainstem System reservoirs. At these reservoirs longitudinal contour plots were constructed for water temperature, dissolved oxygen, and turbidity.

Longitudinal box plots were constructed when adequate measurements were collected along the length of a waterbody. Adequate information was collected to construct longitudinal box plots of existing water quality conditions at all the Mainstem System reservoirs and the lower Missouri River.

Depending on their bathymetry, lakes can experience thermally-induced density stratification in the summer. This can lead to significant vertical water quality variation if anoxic or near-anoxic conditions develop in the hypolimnion. Measured water temperature and dissolved oxygen depth profiles were plotted at the Mainstem System reservoirs and mainstem ancillary lakes. The plotted depth profiles were measured at a near-dam, deepwater ambient monitoring location. Depth profiles measured in the summer months over the past 5 years were plotted. The plots were reviewed to assess the occurrence of thermal stratification and hypolimnetic dissolved oxygen degradation.

The variation of selected parameters with depth was evaluated, where possible, by comparing near-surface and near-bottom samples collected at the Mainstem System reservoirs and ancillary lakes. The compared samples were collected at the near-dam, deepwater monitoring location over the past 5 years. The parameters compared included water temperature, dissolved oxygen, ORP, pH, alkalinity, and various nutrients.

Annual seasonal time series plots of water temperatures measured in the Missouri River immediately upstream and downstream of the Mainstem System reservoirs were constructed to display

temporal variation. Time series plots were also prepared for water quality conditions monitored at the Mainstem System powerplants during 2005 through 2009. Hourly water temperature, dissolved oxygen, and dam discharge were plotted semi-annually for the 5 years.

A lake Trophic State Index (TSI) was calculated from Secchi depth transparency, total phosphorus, and chlorophyll *a* measurements. Values for these three parameters were converted to an index number ranging from 0 to 100. This index value was used to determine the lake's trophic status in accordance with Table 4-1.

The phytoplankton community at the Mainstem System reservoirs was assessed based on collected grab samples. Laboratory analyses consisted of identification of phytoplankton taxa to the lowest practical level and quantification of taxa biovolume. These results were used to determine the relative abundance of phytoplankton taxa at the division level based on the measured biovolumes.

The impairment of beneficial uses designated in State water quality standards was evaluated by applying the impairment assessment criteria defined by the appropriate States.

Surface water quality trends at the Mainstem System reservoirs were assessed by evaluating water clarity (i.e. Secchi depth), total phosphorus, chlorophyll *a*, and trophic state index values from monitoring results obtained at long-term, fixed-station ambient monitoring sites for the 30-year period 1980 through 2009.

<u>Water Quality Conditions Monitored at the Mainstem System Projects</u>

Fort Peck

Monitoring of the existing water quality conditions of Fort Peck Reservoir (Fort Peck Lake) indicated no significant water quality concerns. On a few occasions measured dissolved oxygen concentrations were below the water quality standards criterion of 5 mg/l. The measured low dissolved oxygen concentrations occurred in the hypolimnion near the reservoir bottom during the later part of the summer thermal stratification period. Water temperature, dissolved oxygen, and turbidity in Fort Peck Lake vary temporally, longitudinally from the dam to the reservoir's upper reaches, and vertically from the reservoir's surface to the bottom (Plate 7 - Plate 20). During the summer, a thermocline typically becomes established in the reservoir at a depth of about 20 meters. Parameter that varied significantly from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, pH, and alkalinity. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). Over the past 30 years, Fort Peck Lake exhibited decreasing transparency and increasing chlorophyll *a* and TSI (Trophic State Index). During the 30-year period the lacustrine zone of Fort Peck Lake has generally remained in a mesotrophic state.

Water quality monitoring of the existing conditions of the Fort Peck Dam discharge did not indicate any water quality standards attainment concerns. There appeared to be little correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations (Plate 35 - Plate 54). Inflow temperatures of the Missouri River to Fort Peck Lake are generally warmer than the outflow temperatures of Fort Peck Dam during March through August and cooler than the outflow temperatures during September through February. A maximum temperature difference occurs in the summer when the Missouri River inflow temperature is about 10°C warmer than the Fort Peck Dam outflow temperature. Colder water temperatures and lower turbidity levels, attributed to the regulation of Fort Peck Dam, are believed to be impacting the endangered pallid sturgeon population in the Missouri River downstream of the dam.

Garrison

Monitoring of the existing water quality conditions of Garrison Reservoir (Lake Sakakawea) indicated possible water quality concerns regarding water temperature and dissolved oxygen for the support of coldwater fishery habitat during the drought-attributed low pool levels. Water temperatures in the epilimnion of the reservoir regularly exceed 15°C in the summer, while temperatures in the hypolimnion are less than 15°C. Dissolved oxygen levels in the hypolimnion continually degrade along the reservoir bottom as summer progresses, and can fall below 5.0 mg/l in late summer. Low dissolved oxygen conditions occur in the upstream reaches of the hypolimnion first and progress towards the dam. As the summer progresses, low dissolved oxygen conditions move up from the reservoir bottom into the mid- and upper reaches of the hypolimnion and pinch off coldwater habitat.. This pinching off of coldwater habitat threatens the occurrence of coldwater fishery habitat in Lake Sakakawea, especially under low pool levels during drought conditions.

Water temperature, dissolved oxygen, and turbidity in Lake Sakakawea vary temporally, longitudinally from the dam to the reservoir's upstream reaches, and vertically from the reservoir's surface to the bottom (Plate 68 - Plate 79 and Plate 83 - Plate 87). During the summer, a thermocline typically becomes established in the reservoir at a depth of about 25 meters. Parameters that significantly varied from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, pH, alkalinity, and total organic carbon. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). Over the past 30 years, Lake Sakakawea exhibited no significant trends in transparency, total phosphorus, and chlorophyll *a* levels. Monitoring indicated that the lacustrine zone of Lake Sakakawea is currently in a mesotrophic state and shows no observable trend of an increasing trophic state over the past 30 years.

Water quality monitoring of the existing conditions of the Garrison Dam discharge did not indicate any significant water quality concerns. There is a significant correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations during the summer thermal stratification period of Lake Sakakawea (Plate 103 - Plate 130). This indicates that the vertical extent of the withdrawal zone in the reservoir is dependent upon the discharge rate of the dam. This is believed to be a result of the design of the intake structure (i.e., bottom withdrawal) and the presence of the submerged intake channel leading to the intake structure. Water is likely drawn from an extended vertical zone in Lake Sakakawea year-round, but is only evident in the temperatures monitored at the powerhouse during reservoir thermal stratification during the summer. Inflow temperatures of the Missouri River to Lake Sakakawea are generally warmer than the outflow temperatures of Garrison Dam during April through September and cooler than the outflow temperatures during October through March. A maximum temperature difference occurs in the summer when the Missouri River inflow temperature is about 10°C warmer than the Garrison Dam outflow temperature.

As drought conditions persisted in early 2005, water levels in Lake Sakakawea had fallen to a record low pool elevation of 1805.8 ft-msl on May 12, 2005. At that time it was felt that, unless emergency water quality management measures were implemented in 2005 to preserve the coldwater habitat in the reservoir, the recreational sport fishery would likely be adversely impacted. The reduction of coldwater habitat is exacerbated by withdrawals through the Garrison Dam intake structure. Because the invert elevation of the intake portals to the Garrison Dam power tunnels (i.e., penstocks) is 2 feet above the reservoir bottom, water drawn through the penstocks comes largely from the lower depths of the reservoir. Thus, during the summer thermal-stratification period, water is largely drawn from the hypolimnetic volume of Lake Sakakawea. Three short-term water quality management measures were identified for implementation in 2005 in an effort to preserve the coldwater habitat in the reservoir. These measures, which were implemented at Garrison Dam, included: 1) application of a plywood barrier to the dam's intake trash racks, 2) utilization of head gates to restrict the opening to the dam's power tunnels,

and 3) modification of the daily flow cycle and minimum flow releases from the dam. The three implemented water quality management measures were targeted at drawing water into the dam from higher elevations within Lake Sakakawea. It is estimated the implementation of these short-term water quality management measures resulted in a potential saving of optimal coldwater habitat in Lake Sakakawea of about 379,390 acre-ft in 2005, 1,021,150 acre-ft in 2006, 827,928 acre-ft in 2007, 794,850 acre-ft in 2008, and 87,060 acre-ft in 2009. The smaller potential saving of coldwater habitat in 2009 is attributed to the return of "normal" pool levels in 2009. With the return to "normal" pool levels, the plywood barriers were removed in October 2009.

Oahe

Monitoring of the existing water quality conditions of Oahe Reservoir (Lake Oahe) indicated possible water quality concerns regarding water temperature and dissolved oxygen for the support of Coldwater Permanent Fish Life Propagation. Water temperatures in the epilimnion of the reservoir regularly exceed the criterion of 18.3°C in the summer, while temperatures in the hypolimnion are less than 18.3°C. Dissolved oxygen levels in the hypolimnion continually degrade along the reservoir bottom as summer progresses and fall below the criterion of 7 mg/l in late summer. Dissolved oxygen levels did not fall below the criterion of 6 mg/l in the hypolimnion in the area of the reservoir near Oahe Dam. Dissolved oxygen concentrations regularly fall below 6 mg/l in the middle and upstream reaches of the hypolimnion. As the summer progresses, conditions of lower dissolved oxygen move up from the reservoir bottom into the lower reaches of the hypolimnion.

Water temperature, dissolved oxygen, and turbidity in Lake Oahe vary temporally, longitudinally from the dam to the reservoir's upstream reaches, and vertically from the reservoir's surface to the bottom (Plate 155 - Plate 166 and Plate 168 - Plate 172). During the summer, a thermocline typically becomes established in the reservoir at a depth of about 20 meters. Parameter that significantly varied from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, ORP, pH, and alkalinity. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). Over the past 30 years, Lake Oahe exhibited no significant trends in transparency, total phosphorus, or chlorophyll *a* levels. Monitoring indicated that the lacustrine zone of Lake Oahe is currently in a mesotrophic state; however, recent monitoring indicates a significant trend of an increasing trophic state.

Water quality monitoring of the existing conditions of the Oahe Dam discharge indicated possible water quality concerns regarding temperature and dissolved oxygen for the support of Coldwater Permanent Fish Life Propagation. Temperatures of the water passed through Oahe Dam in the summer regularly exceeded the temperature criterion of 18.3°C. During the summer when Lake Oahe is thermally stratified, water temperatures in the epilimnion of the reservoir exceed 18.3°C, while temperatures in the hypolimnion are less than 18.3°C. Water discharged through Oahe Dam for power production is withdrawn from Lake Oahe at elevation 1525 ft-msl, approximately 110 feet above the reservoir bottom. Thus, water withdrawn from the reservoir in the summer comes largely from the epilimnion, especially when pool elevations are lower due to drought conditions. Because water passed through Oahe Dam during the summer is withdrawn from the epilimnion of the reservoir, the temperature criterion of 18.3°C for the Missouri River and Big Bend Reservoir just downstream of the dam are not being met during the summer when Lake Oahe is thermally stratified. Generally, dissolved oxygen levels were below 7 mg/l from mid July through September. Seemingly, the lower dissolved oxygen levels may be related to lower oxygen solubility with warmer water and possible oxygen degradation in the hypolimnion during late summer.

There appeared to be little correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations (Plate 189 - Plate 208). Inflow temperatures of the Missouri River to Lake Oahe are generally warmer than the outflow temperatures of the Oahe Dam discharge during the period of April through June. Outflow temperatures of the Oahe Dam discharge are generally warmer than the inflow temperatures of the Missouri River during the period of July through March. A maximum temperature difference occurs in the fall when the Oahe Dam discharge temperature is about 4°C warmer than the Missouri River inflow temperature.

Big Bend

Water quality monitoring of the existing conditions of Big Bend Reservoir (Lake Sharpe) indicated possible water quality concerns regarding water temperature and dissolved oxygen for the support of Coldwater Permanent Fish Life Propagation (CPFLP). Due to its shallowness, a hypolimnion rarely forms in Lake Sharpe and water temperatures throughout the reservoir regularly exceed 18.3°C in the summer. Dissolved oxygen levels near the bottom of the reservoir occasionally fall below 6.0 mg/l CPFLP criterion during the summer. Ambient summer water temperatures in Lake Sharpe do not appear to be cold enough to support CPFLP as defined by State water quality criteria. Consideration should be given to reclassify the reservoir for a warmwater permanent fish life propagation use based on a use attainability assessment of "natural conditions" regarding ambient water temperatures.

Lake Sharpe exhibits limited summer thermal stratification due to its shallower depth and the high discharge rates that occur through Big Bend Dam; however, temperature and dissolved oxygen can vary significantly during periods of stratification (Plate 219 - Plate 228). Significant longitudinal variation in turbidity levels occurs on Lake Sharpe, especially following periods of significant inflows from the Bad River (Plate 229 - Plate 232). Parameters that significantly varied from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, pH, and TKN. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). Over the past 30 years, Lake Sharpe exhibited a significant trend for transparency (decreasing) and no significant trends for total phosphorus chlorophyll *a*. Monitoring indicated that the lacustrine zone of Lake Sharpe is currently in a mesotrophic to moderately eutrophic state and shows a significant trend of increasing TSI over the past 30 years.

Monitoring of the existing water quality conditions of the Big Bend Dam discharge did not indicate any water quality concerns. There appeared to be only minor correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations (Plate 246 - Plate 265). Inflow temperatures of the Missouri River to Big Bend Reservoir are about 4°C warmer than the outflow temperatures of Big Bend Dam during the winter. Temperatures of the Big Bend Dam discharge are about 3°C warmer than the inflow temperatures of the Missouri River during the spring, summer, and fall.

Fort Randall

Monitoring of the existing water quality conditions of Fort Randall Reservoir (Lake Francis Case) indicated possible water quality concerns regarding dissolved oxygen and suspended solids for the support of Warmwater Permanent Fish Life Propagation. Dissolved oxygen levels in the hypolimnion degrade along the reservoir bottom as summer progresses and fall below 5.0 mg/l in July and August. The chronic suspended solids criterion was exceeded in Lake Francis Case in the area near the confluence of the White River.

Water temperature, dissolved oxygen, and turbidity in Lake Francis Case vary temporally, longitudinally from the dam to the reservoir's upstream reaches, and vertically from the reservoir's

surface to the bottom (Plate 278 - Plate 294). During the summer, a thermocline typically becomes established in the reservoir at a depth of about 25 meters. Parameters that significantly varied from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, and pH. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). Over the past 30 years, Lake Francis Case exhibited a significant trend in transparency (decreasing), and no significant trends in total phosphorus and chlorophyll *a*. Monitoring indicated that the near-dam lacustrine zone of Lake Francis Case is currently in a mesotrophic state and shows no observable trend of a changing trophic state over the past 30 years.

Water quality monitoring of the existing conditions of the Fort Randall Dam discharge indicated no water quality concerns. There is a significant correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations during the summer thermal stratification period of Lake Francis Case (Plate 308 - Plate 326). This indicates that the vertical extent of the withdrawal zone in the reservoir is dependent upon the discharge rate of the dam. This is believed to be a result of the design of the intake structure (i.e., bottom withdrawal) and the presence of the submerged approach channel leading to the intake structure. Water is likely drawn from an extended vertical zone in Lake Francis Case year-round, but is only evident in the temperature and dissolved oxygen levels monitored at the powerhouse during reservoir thermal stratification during the summer.

Inflow temperatures of the Missouri River to Fort Randall tend to be at little warmer than the outflow temperatures of Fort Randall Dam during the spring and early summer. Outflow temperatures of the Fort Randall Dam discharge tend to be a little warmer than the Missouri River inflow temperatures in the late-summer and fall.

Gavins Point

Water quality monitoring of the existing conditions of Gavins Point Reservoir (Lewis and Clark Lake) indicated a possible water quality concern regarding dissolved oxygen for the support of warmwater aquatic life and nutrients for aesthetics. Based on the criteria for the protection of warmwater aquatic life, several of the near-dam observations did not meet dissolved oxygen criteria. The dissolved oxygen measurements that were below the 5 mg/l criterion occurred near the reservoir bottom in the hypolimnion during the summer on occasions when the reservoir was thermally stratified. Monitored levels of chlorophyll *a*, total nitrogen, and total phosphorus exceed impairment criteria (i.e., 303(d) criteria for listing a waterbody as impaired) identified by the State of Nebraska for the protection of aesthetics. It is also noted that the estimated loss of 23.8 percent of the multi-purpose pool volume of Lewis and Clark Lake is approaching Nebraska's impairment identification criterion of 25 percent volume loss.

Water temperature, dissolved oxygen, and turbidity in Lewis and Clark Lake vary temporally, longitudinally from the dam to the reservoir's upstream reaches, and vertically from the reservoir's surface to the bottom (Plate 339 - Plate 352). During periods of calm weather in the summer, Lewis and Clark Lake develops a slight thermal stratification. When this slight stratification occurs, a thermocline is present at about 8 meters depth. This indicates the reservoir is probably polymixic. The thermal stratification breaks down under windier conditions, given the shallow depth of the reservoir (i.e., 14 meters), and the reservoir mixes throughout its water column. Parameters that significantly varied from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, pH, and total ammonia. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). Over the past 30 years, Lewis and Clark Lake exhibited a significant trend for transparency (decreasing) and no significant trends in total phosphorus and chlorophyll *a* levels. Monitoring indicated that the lacustrine zone of Lewis and Clark Lake is currently in a eutrophic state and shows a slight increasing trend in trophic state.

Water quality monitoring of the existing conditions of the Gavins Point Dam discharge did not indicate any water quality concerns. There appeared to be little correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations (Plate 377 - Plate 396). Inflow temperatures of the Missouri River to Lewis and Clark Lake tend to be at little cooler than the outflow temperatures of Gavins Point Dam during the spring and early summer. Outflow temperatures of the Gavins Point Dam discharge tend to be a little warmer than the Missouri River inflow temperatures in the late-summer and fall.

Comparison of Water Quality Conditions at the Mainstem Reservoirs

A comparison of existing water quality conditions monitored at the Mainstem System reservoirs is provided in Table 5-29 and Table 5-30.

Lower Missouri River

Monitoring of the existing water quality conditions of the lower Missouri River from Gavins Point Dam to Rulo, Nebraska indicated no major water quality concerns. Longitudinal variation in selected water quality parameters was assessed with box plots arranged relative to their respective locations along the Missouri River (Plate 412). Parameters that exhibited no observable longitudinal trend included pH, specific conductance, and total ammonia. Parameters that slightly decreased in a downstream direction included dissolved oxygen. Parameters that slightly increased in a downstream direction included chloride, chemical oxygen demand, total organic carbon, and total Kjeldahl nitrogen. Parameters that greatly increased in downstream direction included turbidity, total suspended solids, nitrate-nitrite nitrogen, and total phosphorus. Mean daily water temperatures monitored along the lower Missouri River during 2009 are plotted in Plate 413.

Existing Nutrient Concentrations and Loadings along the Missouri River from Montana to Nebraska

A box plot of nitrate-nitrite nitrogen, total nitrogen, and total phosphorus concentrations monitored along the Missouri River from near Landusky, Montana to Rulo, Nebraska over the 5-year period 2005 through 2009 is provided in Figure 6-3. A bar chart of estimated mean daily loads of the same nutrients based on calculated flux rates over the 5-year period is provided in Figure 6-4.

Mainstem Ancillary Lakes

Monitoring of existing water quality conditions at Lakes Audubon and Yankton indicated no major water quality concerns. Monitoring at Lake Pocasse indicated that the lake is in a hypereutrophic state.

<u>Water Quality Monitoring and Management Activities Planned for Future Years</u>

A tentative schedule of water quality monitoring targeted for implementation over the next 5 years at the Mainstem System Projects is given in Table 8-1. The identified data collection activities are considered the minimum needed to allow for the annual assessment of water quality conditions at District projects, and the preparation of project-specific water quality reports and water quality management objectives for the Mainstem System Projects. The actual monitoring activities that are implemented will be dependent upon the availability of future resources.

The CE-QUAL-W2 hydrodynamic and water quality model is being applied to facilitate the development project-specific water quality reports and project-specific water quality management objectives. The tentative schedule for implementing these water-quality management planning activities at the Mainstem System Projects is given in Table 8-2.

1 INTRODUCTION

1.1 OMAHA DISTRICT WATER QUALITY MANAGEMENT PROGRAM

The Omaha District (District) of the U.S. Army Corps of Engineers (Corps) is implementing a Water Quality Management Program (WQMP) as part of the operation and maintenance activities associated with managing the Corps' civil works projects in the District. The WQMP addresses surface water quality management issues and adheres to the guidance and requirements specified in the Corps' Engineering Regulation – ER 1110-2-8154, "Water Quality and Environmental Management for Corps Civil Works Projects" (USACE, 1995). The following four goals have been established for the District's WQMP (USACE, 2010):

1) Ensure that surface water quality, as affected by District projects and their regulation, is suitable for Project purposes, existing water uses, and public health and safety, and is in compliance with applicable Federal, Tribal, and State water quality standards.
2) Establish and maintain a surface water quality monitoring and data evaluation program that facilitates the achievement of water quality management objectives, allows for the characterization of water quality conditions, and defines the influence of District Projects on surface water quality.
3) Establish and maintain strong working partnerships and collaboration with appropriate entities within and outside the Corps regarding surface water quality management at District Projects.
4) Document the water quality management activities of the District's Water Quality Management Program and surface water quality conditions at District Projects to record trends, identify problems and accomplishments, and provide guidance to program and Project managers.

Water quality data collection and assessment are of paramount importance to the implementation of the District's WQMP.

The reporting of water quality conditions is done to document and assess water quality conditions occurring at Corps civil works projects in the District. This report describes existing and historic water quality conditions and identifies any evident surface water quality management issues. The reporting of water quality conditions is done to facilitate water quality management decisions regarding the operation and regulation of Corps projects.

1.2 CORPS CIVIL WORKS PROJECTS WITHIN THE OMAHA DISTRICT

The location of Corps Missouri River Mainstem System (Mainstem System) civil works project areas within the District and background information on the projects are provided in Figure 1-1 and Table 1-1. These are the Mainstem System civil works projects under the purview of the District's WQMP.

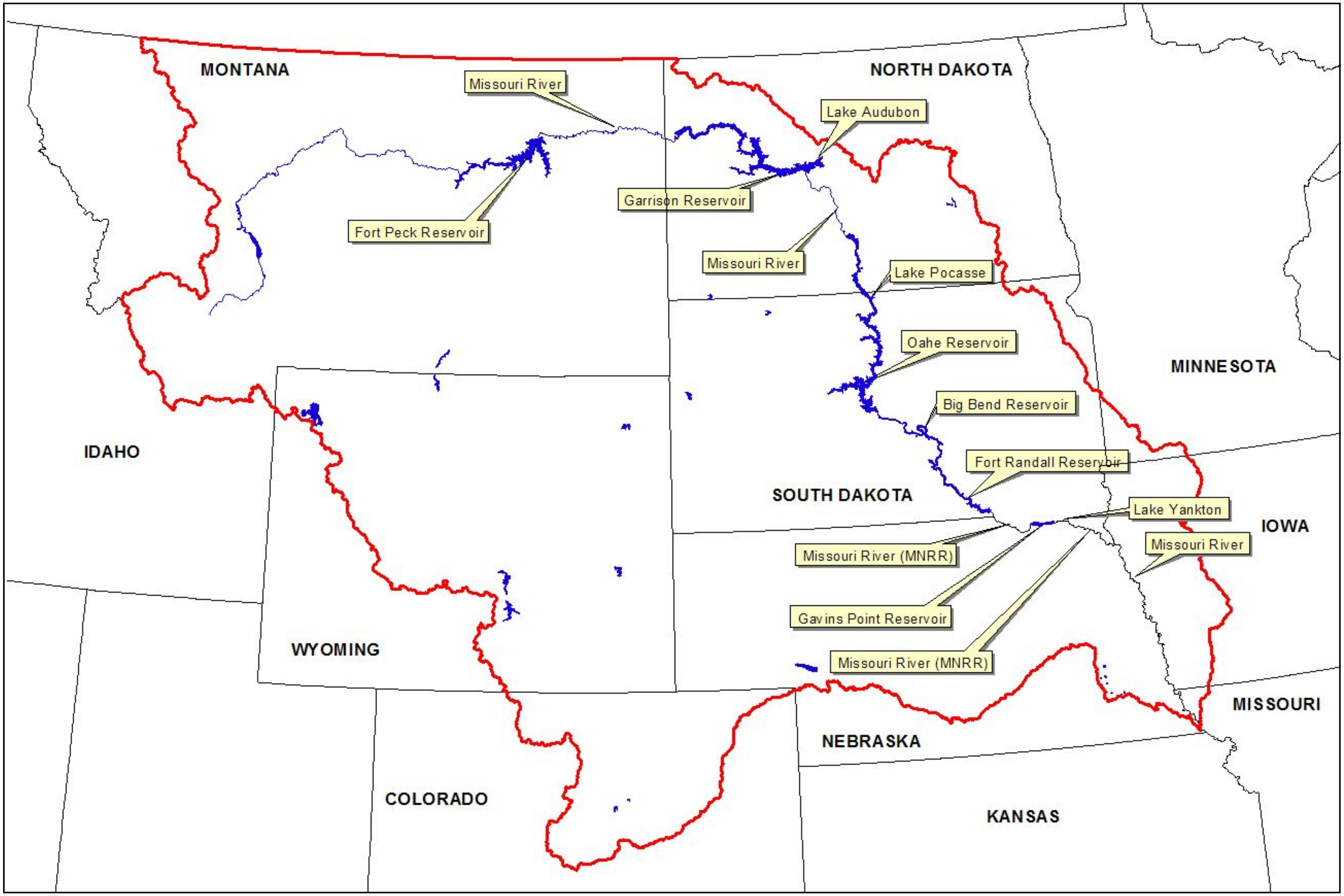

Figure 1-1. Missouri River Mainstem System civil works projects in the Omaha District. (Refer to Table 1-1 for project information.)

Table 1-1. Background information for Corps Missouri River Mainstem System project areas located in the Omaha District**.**

Project Area	Location	Dam Closure	Lake Size or River Length(1)	Authorized Proposes(2)	Water Quality Designated Beneficial Uses(3)
MAINSTEM RESERVOIRS					
Fort Peck (Fort Peck Lake)	Fort Peck, MT	1937	246,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(4)	Rec, FW, WAL, DWS, IWS, AWS
Garrison (Lake Sakakawea)	Garrison, ND	1953	380,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(5)	Rec, FW, CAL, DWS, IWS, AWS
Oahe (Lake Oahe)	Pierre, SD	1958	374,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(4)	Rec, FW, CAL, DWS, IWS, AWS
Big Bend (Lake Sharpe)	Chamberlain, SD	1963	61,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(4)	Rec, FW, CAL, DWS, IWS, AWS
Fort Randall (Lake Francis Case)	Pickstown, SD	1952	102,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(4)	Rec, FW, WAL, DWS, IWS, AWS
Gavins Point (Lewis and Clark Lake)	Yankton, SD	1955	31,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(4)	Rec, FW, WAL, DWS, IWS, AWS, Aes
MAINSTEM RESERVOIR ANCILLARY LAKES					
Lake Audubon (Garrison Project – Snake Creek Dam)	Garrison, ND	1952	18,780 A (mp)	Rec, FW	Rec, FW, WAL, DWS, IWS, AWS
Lake Pocasse (Oahe Project – Spring Creek Dam)	Pollock, SD	1961	1,545 A (mp)	FW	Rec, FW, WAL, AWS
Lake Yankton (Gavins Point Project)	Yankton, SD	1955	250 A	Rec, FW	Rec, WAL, AWS, Aes
MISSOURI RIVER					
Fort Peck Reach	Fort Peck Dam to Lake Sakakawea	-----	204 M	-----	Rec, FW, CAL, WAL, DWS, IWS, AWS
Garrison Reach	Garrison Dam to Lake Oahe	-----	87 M	-----	Rec, FW, WAL, DWS, IWS, AWS
Oahe Reach	Oahe Dam to Lake Sharpe	-----	5 M	-----	Rec, FW, CAL, DWS, IWS, AWS
Fort Randall Reach	Fort Randall Dam to Lewis and Clark Lake	-----	39 M	National Recreational River(6)	Rec, FW, WAL, DWS, IWS, AWS, Aes, OSRW
Gavins Point Reach	Gavins Point Dam to Ponca, NE	-----	59 M	National Recreational River(6)	Rec, FW, WAL, DWS, IWS, AWS, Aes, OSRW
Kensler's Bend Reach	Ponca, NE to Sioux City, IA	-----	17 M	-----	Rec, FW, WAL, DWS, IWS, AWS, Aes, OSRW
Lower Missouri River Reach	Sioux City, IA to Rulo, NE	-----	237 M	BS, Nav	Rec, FW, WAL, DWS, IWS, AWS, Aes

(1) A = acres, M = miles, mp = top of multipurpose pool, cp = top of conservation pool.

(2) Purposes authorized under Federal laws for the operation of the Corps projects.

FC = Flood Control, Rec = Recreation, FW = Fish & Wildlife, HP = Hydroelectric Power, WS = Water Supply, WQ = Water Quality, Nav = Navigation, Irrig = Irrigation, BS = Bank Stabilization.

(3) Water quality dependent beneficial uses designated to the waterbody in State water quality standards pursuant to the Federal Clean Water Act.

Rec = Recreation, FW = Fish and Wildlife, WAL, Warmwater Aquatic Life, CAL = Coldwater Aquatic Life, DWS = Domestic Water Supply, IWS = Industrial Water Supply, AWS = Agricultural Water Supply, Aes = Aesthetics, OSRW = Outstanding State Resource Water.

(4) Section 8 (PL 78-534) Federal irrigation has not been developed at this project; however, water is being withdrawn for private irrigation use.

(5) There is a Section 8 Federal irrigation project authorized at this project, but it is not yet operational; however, water is being withdrawn for private irrigation use.

(6) Designated a Recreational River under the Federal Wild and Scenic Rivers Act.

1.3 WATER QUALITY MONITORING GOALS AND OBJECTIVES

The District has established purposes and monitoring objectives for surface water quality monitoring under its WQMP. These monitoring purposes and objectives were established to meet the water quality information needs of the WQMP and the water quality management objectives, data collection rules and objectives, data application guidance, and reporting requirements identified in ER 1110-2-8154. The following purposes and monitoring objectives have been identified:

Purpose 1: Determine surface water quality conditions at District Projects.

Monitoring Objectives:

- For new District water resource projects, establish baseline surface water quality conditions as soon as possible and appropriate.
- Characterize the spatial and temporal distribution of surface water quality conditions at District Projects.
- Identify pollutants and their sources that are impacting surface water quality and the aquatic environment at District Projects.
- Evaluate water/sediment interactions and their impact on overall surface water quality at District Projects.
- Identify the presence and concentrations of contaminants in indicator and human-consumed fish species at District Projects.
- Investigate unique events (e.g., fish kills, hazardous waste spills, operational emergencies, health emergencies, public complaints, etc.) at District Projects that may have degraded surface water quality or indicate the aquatic environment has been impacted.

Purpose 2: Document surface water quality concerns that are due to the operation and reservoir regulation of District Projects.

Monitoring Objectives:

- Determine if surface water quality conditions at District Projects or attributable to District operations or reservoir regulation (i.e., downstream conditions resulting from reservoir discharges) meets applicable Federal, Tribal, and State water quality standards.
- Determine if surface water quality conditions at District Projects or attributable to District operations or reservoir regulation are improving, degrading, or staying the same over time.
- Apply water quality models to assess surface water quality conditions at District Projects.

Purpose 3: Provide data to support Project operations and reservoir regulation for effective management and enhancement of surface water quality and the aquatic environment.

Monitoring Objectives:

- Provide surface water quality data required for real-time regulation of District Projects.
- Collect the information needed to design, engineer, and implement measures or modifications at District Projects to enhance surface water quality and the aquatic environment.

Purpose 4: Evaluate the effectiveness of structural or regulation measures implemented at District Projects to enhance surface water quality and the aquatic environment.

Monitoring Objectives:

- Evaluate the effectiveness of implemented measures at District Projects to improve surface water quality and the aquatic environment.

1.4 DATA COLLECTION APPROACHES

Several data collection approaches have been identified by the District for collecting surface water quality data. Pertinent water quality monitoring approaches are:

- Long-term, fixed-station ambient monitoring;
- Intensive surveys;
- Special studies; and
- Investigative monitoring.

Long-term, fixed-station ambient monitoring is intended to provide information that will allow the District to determine the status and trends of surface water quality conditions at District Projects. This type of sampling consists of systematically collecting samples at the same location over a long period of time (e.g., collecting monthly water samples at the same site for several years).

Intensive surveys are intended to provide more detailed information regarding surface water quality conditions at District Projects. They typically will include more sites sampled over a shorter timeframe than long-term fixed-station monitoring. Intensive surveys will provide the detailed water quality information needed to thoroughly understand surface water quality conditions at a project.

Special studies are conducted to address specific information needs. Special water quality studies may be undertaken to collect the information needed to "scope-out" a specific water quality problem, apply water quality models, design and engineer modifications at Projects, or evaluate the effectiveness of implemented water quality management measures.

Investigative monitoring is typically initiated in response to an immediate need for surface water quality information at a District Project. This may be in response to an operational situation, the occurrence of a significant pollution event, public complaint, or a report of a fish kill. Any District response to a pollution event or fish kill would need to be coordinated with the appropriate Federal, Tribal, State, and Local agencies. The type of sampling that is done for investigative purposes is highly specific to the situation under investigation.

1.5 GENERAL WATER QUALITY CONCERNS IN THE OMAHA DISTRICT

1.5.1 RESERVOIR EUTROPHICATION AND HYPOLIMNETIC DISSOLVED OXYGEN DEPLETION

Reservoirs are commonly classified or grouped by trophic or nutrient status. The natural progression of reservoirs through time is from an oligotrophic (i.e., low nutrient/low productivity) through a mesotrophic (i.e., intermediate nutrient/intermediate productivity) to a eutrophic (i.e., high nutrient/high productivity) condition. The tendency toward the eutrophic or nutrient-rich status is common to all impounded waters. The eutrophication, or enrichment process, can be accelerated by nutrient additions to the reservoir resulting from cultural activities.

As deeper, temperate lakes warm in the spring and summer they typically become thermally stratified, due to the density differences of the water, into three vertical zones: 1) epilimnion, 2) metalimnion, and 3) hypolimnion. The epilimnion is the upper zone of less dense, warmer water in the lake that remains relatively mixed due to wind action and convection. The metalimnion is the middle zone that represents the transition from warm surface water to cooler bottom water. The hypolimnion is the bottom zone of more dense, colder water that is relatively quiescent.

A significant water quality concern that can occur in reservoirs that thermally stratify in the summer is the depletion of dissolved oxygen levels in the hypolimnion. The depletion of dissolved oxygen is attributed to the differing density of water with temperature, the utilization of dissolved oxygen in the decomposition of organic matter, and the oxidation of reduced inorganic substances. When density differences become significant, the deeper colder water is isolated from the surface and re-oxygenation from the atmosphere. In eutrophic lakes, the decomposition of the abundant organic matter can significantly reduce dissolved oxygen in the quiescent hypolimnetic zone. Hypoxic conditions in the hypolimnion can result in the release of sediment-bound substances (e.g., phosphorus, metals, sulfides, etc.) as the reduced conditions intensify and result in the production of toxic and caustic substances (e.g., hydrogen sulfide, etc.). Most fish and other intolerant aquatic life cannot inhabit water with less than 4 to 5 mg/l dissolved oxygen for extended periods. These conditions can impact aquatic life in the reservoir and also in waters downstream of the reservoir if its releases are from a bottom outlet.

1.5.2 SEDIMENTATION

Sedimentation is a process that reduces the usefulness of reservoirs. In the design and construction of reservoirs, the Corps will commonly allow for additional volume to accommodate sedimentation. The incoming sediment can seriously affect the reservoir ecology, fisheries, and benthic aquatic life. The reservoir can suffer ecological damage before a volume function such as flood control is impacted. The influx of sediment eliminates fish habitat, adds nutrients, destroys aesthetics, and decreases biodiversity. Working closely with the project sponsors in an effort to manage sediment input could ultimately prolong reservoir life. Wetlands or sediment traps could be constructed at the headwaters of a reservoir, either upstream of the reservoir or in a portion of the reservoir's upper end, to trap sediment.

1.5.3 SHORELINE EROSION

Shoreline erosion is a major problem occurring on nearly all reservoirs located in areas of erodible soils such as the Midwestern United States. Over 6,000 miles of reservoir shoreline exist at District Projects, and it is estimated that over 70 percent of this shoreline is eroding. Some locations have been protected, such as recreational and archaeological sites, but most of the shoreline continues to erode. Continued loss of the shoreline habitat (littoral zone) results in the loss of fishery habitat as well as loss of habitat for other biota such as aquatic vegetation and benthic invertebrates.

1.5.4 BIOACCUMULATION OF CONTAMINANTS IN AQUATIC ORGANISMS

Bioaccumulation is the accumulation of contaminants in the tissue of organisms through any route, including respiration, ingestion, or direct contact with contaminated water or sediment. Bioavailable, for chemicals, is the state of being potentially available for biological uptake by an aquatic organism when that organism is processing or encountering a given environmental medium (e.g., the chemicals that can be extracted by the gills from the water as it passes through the respiratory cavity or the chemicals that are absorbed by internal membranes as the organism moves through or ingests sediment). In the aquatic environment, a chemical can exist in three different basic forms that affect availability to organisms: 1) dissolved, 2) sorbed to biotic or abiotic components and suspended in the water column or deposited on the bottom, and 3) incorporated (accumulated) into organisms. Bioconcentration is a process by which there is a net accumulation of a chemical directly from water into aquatic organisms resulting from simultaneous uptake (e.g., by gill or epithelial tissue) and elimination. Biomagnification is the result of the process of bioconcentration and bioaccumulation by which tissue concentrations of bioaccumulated chemicals increase as the chemical passes up through two or more trophic levels. The term implies an efficient transfer of a chemical from food to consumer so that residual concentrations increase systematically from one trophic level to the next.

Bioaccumulation of contaminants can have a direct effect on aquatic organisms. These effects can be chronic (reduced growth, fecundity, etc.) and acute (lethality). The bioaccumulation of contaminants can also be a concern to human health when the contaminated tissue of aquatic organisms is consumed by humans.

1.5.5 OCCURRENCE OF PESTICIDES

Pesticides are widely applied to lands throughout the District. Pesticides detected at District Projects over the past 5 years include: acetochlor, alachlor, atrazine, deethylatrazine, deisopropylatrazine, metolachlor, metribuzin, and propazine. Many of these pesticides do not have State or Federal numeric water quality criteria established.

1.5.6 URBANIZATION

Construction methods used to develop urban areas disturb the land and allow sediment-laden runoff to impact nearby streams and lakes. Best management practices (BMPs) to minimize construction-associated sedimentation damages are used ineffectively in many cases. BMPs to control the impact of construction practices include; sediment retention basins, phased "grading", and runoff control (e.g. hay bales, silt fences, vegetative ground cover, terracing, etc). Efforts need to be made to prevent sedimentation from off-project construction activities from causing impacts to District Projects. This could be accomplished by the appropriate State, County, or City agencies working with developers.

Post-construction problems may be associated with storm drainage and urban pollution. The conversion of grasslands or forests to roads, rooftops, sidewalks, and other water impervious surfaces make stream flows more variable and increase the frequency of high flow events. In addition, pollutants associated with urban drainage can impact downstream waterbodies. Storm sewer outlets can be allowed on Project lands provided detention in the form of ponds, swales, or wetlands exist on private property. A developer may be asked to construct a series of wetlands to slow downhill flows and provide time for bacterial die-off, chemical degradation, reduced flow rates, and sediment settling.

1.6 PRIORITIZATION OF DISTRICT-WIDE WATER QUALITY MANAGEMENT ISSUES

The District has identified eight priority issues for water quality management. These priority issues are listed in Table 1-2.

Table 1-2. Priority water quality management issues within the Omaha District.

	Missouri River Mainstem System Water Quality Management Issues
➢	Determine how regulation of the Missouri River Mainstem System (Mainstem System) dams affects water quality in the impounded reservoir and downstream river. Utilize the CE-QUAL-W2 hydrodynamic and water quality model to facilitate this effort.
➢	Evaluate how eutrophication is progressing in the Mainstem System reservoirs, especially regarding the expansion of anoxic conditions in the hypolimnion during summer stratification.
➢	Determine how flow regime, especially the release of water from Mainstem System projects, affects water quality in the Missouri River.
➢	Determine how current water quality conditions in the Missouri River (e.g., water temperature, turbidity, etc.) may be affecting pallid sturgeon populations in the Missouri River system.
	District-Wide Water Quality Management Issues
➢	Provide water quality information to support Corps reservoir regulation elements for effective surface water quality and aquatic habitat management.
➢	Provide water quality information and technical support to the Tribes and States in the development of their Section 303(d) lists and development and implementation of TMDLs at District Projects.
➢	Identify existing and potential surface water quality problems at District Projects and develop and implement appropriate solutions.
➢	Evaluate surface water quality conditions and trends at District Projects.

1.7 PROJECT-SPECIFIC WATER QUALITY MANAGEMENT ISSUES AT THE MAINSTEM SYSTEM PROJECTS

1.7.1 SECTION 303(D) LISTINGS OF IMPAIRED WATERS

Under Section 303(d) of the Federal Clean Water Act (CWA), Tribes and States, with the delegated authority from the U.S. Environmental Protection Agency (EPA), are required to prepare a periodic list of impaired waters [i.e., Section 303(d) list]. Impaired waters refer to those waterbodies where it has been determined that technology-based effluent limitations required by Section 301 of the CWA are not stringent enough to attain and maintain applicable water quality standards. Tribes and States, as appropriate, are required to establish and implement Total Maximum Daily Loads (TMDLs) for waterbodies on their Section 303(d) lists.

1.7.2 FISH CONSUMPTION ADVISORIES

Fish are capable of accumulating many toxic substances in excess of 1,000 times the concentrations found in surface waters. The public has expressed concerns on whether fish caught from District Project waters are safe to consume. It is important that answers to public health concerns be based on substantiated knowledge of toxicants in fish fillets and the public health risks associated with measured toxicant concentrations. This type of information can be used by States when considering the issuance of fish consumption advisories. Fish consumption advisories have been issued for fish caught from certain District Project waters. Mercury is the most prevalent contaminant leading to the issuance of fish consumption advisories in the District.

1.7.3 SUMMARY OF PROJECT-SPECIFIC TMDL CONSIDERATIONS, FISH CONSUMPTION ADVISORIES, AND OTHER WATER QUALITY MANAGEMENT ISSUES

Table 1-3 summarizes TMDL considerations, fish consumption advisories, and other water quality management issues applicable to the Mainstem System Projects. The impaired uses and pollutant/stressors (i.e., TMDL considerations) and identified contamination (i.e., Fish Consumption Advisories) identified in Table 1-3 are taken directly from the appropriate State 303(d) impaired waters listings and issued fish consumption advisories. They are provided for information purposes and are not based on water quality monitoring conducted by the District. The listed other water quality management issues in Table 1-3 were identified by the District based on water quality monitoring and Corps water quality management concerns. Water quality management issues at specific Mainstem System Projects will be assessed in detail in Project-Specific Reports (USACE, 2010) prepared for the Project by the District.

Table 1-3. Summary of site-specific water quality management issues and concerns for Missouri River Mainstem System projects areas in the Omaha District.

Project Area	TMDL Considerations*				Fish Consumption Advisories		Other Water Quality Management Issues
	On 303(d) List	Impaired Uses	Pollutant/Stressor	TMDL Completed	Advisory in Effect	Identified Contamination	
Missouri River (Bullwhacker Creek to Fort Peck Reservoir)	Yes	Aquatic Life Drinking Water Supply Warmwater Fishery	Alteration Riparian Vegetation Arsenic Copper	No	No	-----	Pallid sturgeon recovery priority area
Fort Peck Lake	Yes	Drinking Water Supply	Lead, Mercury	No	Yes	Mercury	-----
Missouri River (Fort Peck Dam to the Milk River)	Yes	Aquatic Life Coldwater Fishery	Water Temperature	No	No	-----	Pallid sturgeon recovery priority area
Missouri River (Milk River to the Poplar River)	Yes	Aquatic Life Warmwater Fishery	Water Temperature	No	No	-----	Pallid sturgeon recovery priority area
Missouri River (Poplar River to MT/ND State line)	Yes	Aquatic Life Warmwater Fishery	Water Temperature	No	No	-----	Pallid sturgeon recovery priority area
Lake Sakakawea	Yes	Fish and Other Aquatic Biota Fish Consumption	Low Dissolved Oxygen Water Temperature Methyl-Mercury	No	Yes	Mercury	Hypolimnetic dissolved oxygen
Missouri River (Garrison Dam tailwaters)	No	-----	-----	-----	Yes	Mercury	Low dissolved oxygen in Garrison Dam tailwaters (associated with late summer hypolimnetic reservoir withdrawals)
Lake Oahe (Cheyenne River Area)	No	----	-----	-----	Yes	Mercury	Issued by the Cheyenne River Sioux Tribe for Lake Oahe, Cheyenne River, and Moreau River within their tribal lands.
Lake Pocasse (Lake Oahe)	Yes	Warmwater Fishery	Trophic State Index (Eutrophication)	No	No	-----	-----
Lake Sharpe	No	-----	Sediment	Yes	No	-----	TMDL developed for sediment. A nonpoint source management project is being implemented in the Bad River watershed.
Missouri River (Fort Randall Dam to Lewis and Clark Lake)	No	-----	-----	-----	No	-----	National recreational river Pallid sturgeon recovery priority area
Lewis and Clark Lake	No	-----	-----	-----	No	-----	Sedimentation Emergent aquatic vegetation
Missouri River (Gavins Pt Dam to Rulo, NE)							Pallid sturgeon recovery priority area
• Gavins Pt Dam to Big Sioux River	No			-----	No		National recreational river
• Big Sioux River to Platte River	Yes	Aquatic Life	Dieldrin, PCBs	No	Yes	Dieldrin PCBs	Summer ambient water temperature (NPDES limitations regarding cooling water discharges)
• Council Bluffs, IA)	Yes	Drinking Water Supply	Arsenic	No	-----	-----	-----
• Platte River to Nebraska-Kansas Border	Yes	Recreation Aquatic Life	*E. coli* Bacteria Dieldrin, PCBs	Yes/No	Yes	Dieldrin PCBs	TMDL developed for *E. coli*. Summer ambient water temperature (NPDES limitations regarding cooling water discharges)

* Information taken from published State Total Maximum Daily Load (TMDL) 303(d) reports and listings as of January 1, 2010.

2 LIMNOLOGICAL PROCESSES IN RESERVOIRS

Many of the Corps civil works projects in the District involve the operation and maintenance of a reservoir or the regulation of flows discharged from reservoirs. Much of the water quality monitoring conducted by the District is done to determine existing water quality conditions and identify water quality management concerns at these reservoirs. A basic understanding of the limnological processes that occur in reservoirs is needed to interpret the water quality information provided in this report. The following discussion provides a basic overview of limnological processes that occur in reservoirs.

2.1 VERTICAL AND LONGITUDINAL WATER QUALITY GRADIENTS

The annual temperature distribution represents one of the most important limnological processes occurring within a reservoir. Thermal variation in a reservoir results in temperature-induced density stratification, and an understanding of the thermal regime is essential to water quality assessment. Deep, temperate-zone lakes typically completely mix from the surface to the bottom twice a year (i.e., dimictic). Temperate-zone dimictic lakes exhibit thermally-induced density stratification in the summer and winter months that is separated by periods of "turnover" in the spring and fall. This stratification typically occurs through the interaction of wind and solar insolation at the lake surface and creates density gradients that can influence lake water quality. During the summer, solar insolation has its highest intensity and the reservoir becomes stratified into three zones: 1) epilimnion, 2) metalimnion, and 3) hypolimnion.

<u>Epilimnion</u>: The epilimnion is the upper zone that consists of the less dense, warmer water in the reservoir. It is fairly turbulent since its thickness is determined by the turbulent kinetic energy inputs (e.g., wind, convection, etc.), and a relatively uniform temperature distribution throughout this zone is maintained.

<u>Metalimnion</u>: The metalimnion is the middle zone that represents the transition from warm surface water to colder bottom water. There is a distinct temperature gradient through the metalimnion. The metalimnion contains the thermocline that is the plane or surface of maximum temperature rate change.

<u>Hypolimnion</u>: The hypolimnion is the bottom zone of more dense, colder water that is relatively quiescent. Bottom withdrawal or fluctuating water levels in reservoirs, however, may significantly increase hypolimnetic mixing.

Long, dendritic reservoirs with tributary inflows located a considerable distance from the outflow and unidirectional flow from headwater to dam develop gradients in space and time (USACE, 1987). Although these gradients are continuous from headwater to dam, three characteristic zones result: a riverine zone, a zone of transition, and a lacustrine zone (USACE, 1987).

<u>Riverine Zone:</u> The riverine zone is relatively narrow and well mixed, and there is a significant decrease in water current velocities. Advective forces are still sufficient to transport significant quantities of suspended particles, such as silts, clays, and organic particulate. Light penetration in this zone is minimal and may be the limiting factor that controls primary productivity in the water column. The decomposition of tributary organic loadings often creates a significant oxygen demand, but an aerobic environment is maintained because the riverine zone is generally shallow and well mixed. Longitudinal dispersion may be an important process in this zone.

<u>Zone of Transition:</u> Significant sedimentation occurs through the transition zone, with a subsequent increase in light penetration. Light penetration may increase gradually or abruptly, depending on the flow regime. At some point within the mixed layer of the zone of transition, a

compensation point between the production and decomposition of organic matter should be reached. Beyond this point, production of organic matter within the reservoir mixed layer should begin to dominate.

Lacustrine Zone: The lacustrine zone is characteristic of a lake system. Sedimentation of inorganic particulate is low. Light penetration is sufficient to promote primary production, with nutrient levels the limiting factor and production of organic matter exceeds decomposition within the mixed layer. Entrainment of metalimnetic and hypolimnetic water, particulate, and nutrients may occur through internal waves or wind mixing during the passage of large weather fronts. Hypolimnetic mixing may be more extensive in reservoirs than "natural" lakes because of bottom withdrawal. In addition, an intake structure may simultaneously remove water from the hypolimnion and metalimnion.

When tributary inflow enters a reservoir, it displaces the reservoir water. If there is no density difference between the inflow and reservoir waters, the inflow will mix with the reservoir water as the inflow water moves toward the dam. However, if there are density differences between the inflow and reservoir waters, the inflow moves as a density current in the form of overflows, interflows, or underflows. Internal mixing is the term used to describe mixing within a reservoir from such factors as wind, Langmuir circulation, convection, Kelvin-Helmholtz instabilities, and outflow (USACE, 1987).

2.2 CHEMICAL CHARACTERISTICS OF RESERVOIR PROCESSES

2.2.1 CONSTITUENTS

Some of the most important chemical constituents in reservoir waters that affect water quality are needed by aquatic organisms for survival. These include oxygen, carbon, nitrogen, and phosphorus. Other important constituents are silica, manganese, iron, and sulfur.

Dissolved oxygen: Oxygen is a fundamental chemical constituent of waterbodies that is essential to the survival of aquatic organisms and is one of the most important indicators of reservoir water quality conditions. The distribution of dissolved oxygen (DO) in reservoirs is a result of dynamic transfer processes from the atmospheric and photosynthetic sources to consumptive uses by the aquatic biota. The resulting distribution of DO in the reservoir water strongly affects the solubility of many inorganic chemical constituents. Often, water quality control or management approaches are formulated to maintain an aerobic, or oxic (i.e., oxygen-containing), environment. Oxygen is produced by aquatic plants (phytoplankton and macrophytes) and is consumed by aquatic plants, other biological organisms, and chemical oxidations. In reservoirs, the DO demand may be divided into two separate but highly interactive fractions: sediment oxygen demand (SOD) and water column oxygen demand.

Sediment oxygen demand: The SOD is typically highest in the upstream area of the reservoir just below the headwaters. This is an area of transition from riverine to lake characteristics. It is relatively shallow but stratifies. The loading and sedimentation of organic matter is high in this transition area and, during stratification, the hypolimnetic DO to satisfy this demand can be depleted. If anoxic conditions develop, they generally do so in this area of the reservoir and progressively move toward the dam during the stratification period. The SOD is relatively independent of DO when DO concentrations in the water column are greater than 3 to 4 mg/l but becomes limited by the rate of oxygen supply to the sediments.

Water column oxygen demand: A characteristic of many reservoirs is a metalimnetic minimum in DO concentrations, or negative heterograde oxygen curve (Figure 2-1). Density interflows not only transport oxygen-demanding material into the metalimnion but can also entrain reduced chemicals from the upstream anoxic area and create additional oxygen demand. Organic matter and organisms from the mixed layer settle at slower rates in the metalimnion because of increased

viscosity due to lower temperatures. Since this labile organic matter remains in the metalimnion for a longer time period, decomposition occurs over a longer time, exerting a higher oxygen demand. Metalimnetic oxygen depletion is an important process in deep reservoirs. A hypolimnetic oxygen demand generally starts at the sediment/water interface unless underflows contribute organic matter that exerts a significant oxygen demand. In addition to metalimnetic DO depletion, hypolimnetic DO depletion also is important in shallow, stratified reservoirs since there is a smaller hypolimnetic volume of oxygen to satisfy oxygen demands than in deeper reservoirs.

Dissolved oxygen distribution: Two basic types of vertical DO distribution may occur in the water column: an orthograde and clinograde DO distribution (Figure 2-1). In the orthograde distribution, DO concentration is a function primarily of temperature since DO consumption is limited. The clinograde DO profile is representative of more productive, nutrient-rich reservoirs where the hypolimnetic DO concentration progressively decreases during stratification and can occur during both summer and winter stratification periods.

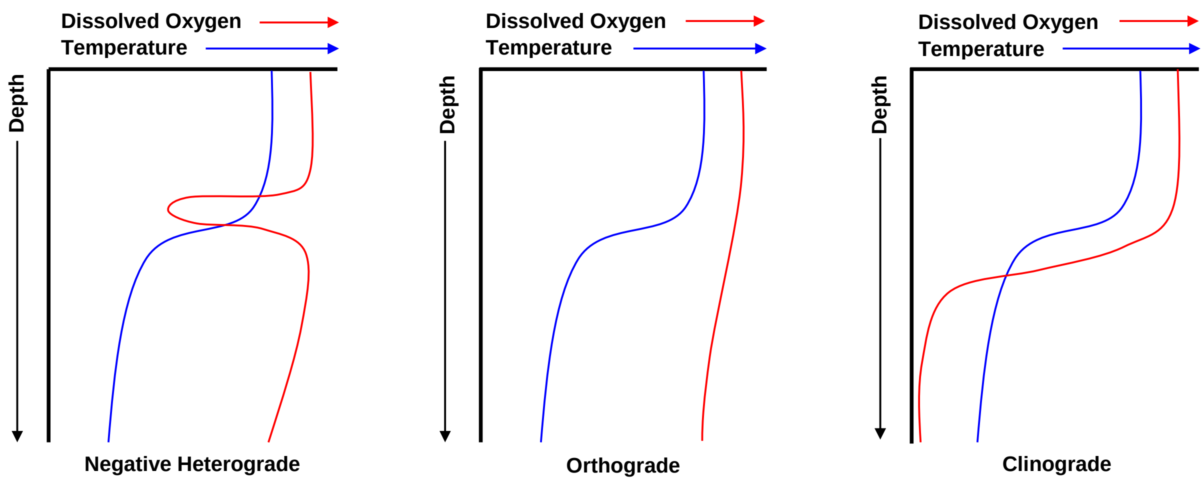

Figure 2-1. Vertical oxygen concentrations possible in thermally stratified lakes.

Inorganic carbon: Inorganic carbon represents the basic building block for the production of organic matter by plants. Inorganic carbon can also regulate the pH and buffering capacity or alkalinity of aquatic systems. Inorganic carbon exists in a dynamic equilibrium in three major forms: carbon dioxide (CO_2), bicarbonate ions (HCO_3), and carbonate ions (CO_3). Carbon dioxide is readily soluble in water and some CO_2 remains in a gaseous form, but the majority of the CO_2 forms carbonic acid that dissociates rapidly into HCO_3 and CO_3 ions. This dissociation results in a weakly alkaline system (i.e., pH ≈ 7.1 or 7.2). There is an inverse relationship between pH and CO_2. The pH increases when aquatic plants (phytoplankton or macrophytes) remove CO_2 from the water to form organic matter through photosynthesis during the day. During the night when aquatic plants respire and release CO_2, the pH decreases. The extent of this pH change provides an indication of the buffering capacity of the system. Weakly buffered systems with low alkalinities (i.e., <500 microequivalents per liter) experience larger shifts in pH than well-buffered systems (i.e., >1,000 microequivalents per liter).

Nitrogen: Nitrogen is important in the formulation of plant and animal protein. Nitrogen, similar to carbon, also has a gaseous form. Many species of cyanobacteria can use or fix elemental or gaseous N_2 as a nitrogen source. The most common forms of nitrogen in aquatic systems are ammonia (NH_3-N), nitrite (NO_2-N), and nitrate (NO_3-N). All three forms are transported in water in a dissolved phase. Ammonia results primarily from the decomposition of organic matter. Nitrite is primarily an intermediate compound in the oxidation or nitrification of ammonia to nitrate, while nitrate is the stable oxidation state of nitrogen and represents the other primary inorganic nitrogen form, besides NH_3, used by aquatic plants.

Phosphorus: Phosphorus is used by both plants and animals to form enzymes and vitamins and to store energy in organic matter. Phosphorus has received considerable attention as the nutrient controlling algal production and densities and associated water quality problems. The reasons for this emphasis are: phosphorus tends to limit plant growth more than the other major nutrients; phosphorus does not have a gaseous phase and ultimately originates from the weathering of rocks; removal of phosphorus from point sources can reduce the growth of aquatic plants; and the technology for removing phosphorus is more advanced and less expensive than nitrogen removal. Phosphorus is generally expressed in terms of the chemical procedures used for measurement: total phosphorus, particulate phosphorus, dissolved or filterable phosphorus, and soluble reactive phosphorus. Phosphorus is a very reactive element; it reacts with many cations such as iron and calcium and is readily sorbed on particulate matter such as clays, carbonates, and inorganic colloids. Since phosphorus exists in a particulate phase, sedimentation represents a continuous loss from the water column to the sediment. Sediment phosphorus, then, may exhibit longitudinal gradients in reservoirs similar to sediment silt/clay gradients. Phosphorus contributions from sediment under anoxic conditions and macrophyte decomposition are considered internal phosphorus sources or loads, and are in a chemical form readily available for plankton uptake and use. Internal phosphorus loading can represent a major portion of the total phosphorus budget.

Silica: Silica is an essential component of diatom algal frustules or cell walls. Silica uptake by diatoms can markedly reduce silica concentrations in the epilimnion and initiate a seasonal succession of diatom species. When silica concentrations decrease below 0.5 mg/l, diatoms generally are no longer competitive with other phytoplankton species.

Other nutrients: Iron, manganese, and sulfur concentrations generally are adequate to satisfy plant nutrient requirements. Oxidized iron (III) and manganese (IV) are quite insoluble in water and occur in low concentrations under aerobic conditions. Under aerobic conditions, sulfur usually is present as sulfate.

2.2.2 ANAEROBIC (HYPOXIC AND ANOXIC) CONDITIONS

When dissolved oxygen concentrations are reduced to approximately 2 to 3 mg/l, the oxygen regime is considered hypoxic. Anoxic conditions occur when there is a complete lack of oxygen. When hypoxic conditions occur in the hypolimnion, the oxygen regime at the sediment/water interface is generally considered anoxic, and anaerobic processes begin to occur in the sediment interstitial water. Nitrate reduction to ammonium and/or N_2O or N_2 (denitrification) is considered to be the first phase of the anaerobic process and places the system in a slightly reduced electrochemical state. Ammonium-nitrogen begins to accumulate in the hypolimnetic water. The presence of nitrate prevents the production of additional reduced forms such as manganese (II), iron (II), or sulfide species. Denitrification probably serves as the main mechanism for removing nitrate from the hypolimnion. Following the reduction or denitrification of nitrate, manganese species are reduced from insoluble forms (i.e., Mn (IV)) to soluble manganous forms (i.e., Mn (II)), which diffuse into the overlying water column. Nitrate reduction is an important step in anaerobic processes since the presence of nitrate in the water column will inhibit manganese reduction. As the electrochemical potential of the system becomes further reduced, iron is reduced from the insoluble ferric (III) form to the soluble ferrous (II) form and begins to diffuse into the overlying water column. Phosphorus, in many instances, is also transported in a complexed form with insoluble ferric (III) species; therefore, the reduction and solubilization of iron also result in the release and solubilization of phosphorus into the water column. The sediments may serve as a major phosphorus source during anoxic periods and a phosphorus sink during aerobic periods. During this period of anaerobiosis, microorganisms also are decomposing organic matter into lower molecular weight acids and alcohols such as acetic, fulvic, humic, and citric acids and methanol. These compounds may also serve as trihalomethane precursors (low-molecular weight organic compounds in water; i.e., methane, formate acetate), which, when subject to chlorination during water treatment, form trihalomethanes, or THMs

(carcinogens). As the system becomes further reduced, sulfate is reduced to sulfide, which begins to appear in the water column. Sulfide will readily combine with soluble reduced iron (II), however, to form insoluble ferrous sulfide, which precipitates out of solution. If the sulfate is reduced to sulfide and the electrochemical potential is strongly reducing, methane formation from the reduced organic acids and alcohols may occur. Consequently, water samples from anoxic depths will exhibit these chemical characteristics.

Anaerobic processes are generally initiated in the upstream portion of the hypolimnion where organic loading from the inflow is relatively high and the volume of the hypolimnion is minimal, so oxygen depletion occurs rapidly. Anaerobic conditions are generally initiated at the sediment/water interface and gradually diffuse into the overlying water column and downstream toward the dam. Anoxic conditions may also develop in a deep pocket near the dam due to decomposition of autochthonous organic matter settling to the bottom. This anoxic pocket, in addition to expanding vertically into the water column, may also move upstream and eventually meet the anoxic zone moving downstream.

Anoxic conditions are generally associated with the hypolimnion, but anoxic conditions may occur in the metalimnion. The metalimnion may become anoxic due to microbial respiration and decomposition of plankton settling into the metalimnion, microbial metabolism of organic matter entering as an interflow, or entrainment of anoxic hypolimnetic water from the upper portion of the reservoir.

2.3 BIOLOGICAL CHARACTERISTICS AND PROCESSES

2.3.1 MICROBIOLOGICAL

The microorganisms associated with reservoirs may be categorized as pathogenic or nonpathogenic. Pathogenic microorganisms are of a concern from a human health standpoint and may limit recreational and other uses of reservoirs. Nonpathogenic microorganisms are important in that they often serve as decomposers of organic matter and are a major source of carbon and energy for a reservoir. Microorganisms generally inhabit all zones of the reservoir as well as all layers. Seasonally high concentrations of bacteria will occur during the warmer months, but they can be diluted by high discharges. Anaerobic conditions enhance growth of certain bacteria while aeration facilitates the use of bacterial food sources. Microorganisms, bacteria in particular, are responsible for mobilization of contaminants from sediments.

2.3.2 PHOTOSYNTHESIS

Oxygen is a by-product of aquatic plant photosynthesis, which represents a major source of oxygen for reservoirs during the growing season. Oxygen solubility is less during the period of higher water temperatures, and diffusion may also be less if wind speeds are lower during the summer than the spring or fall. Biological activity and oxygen demand typically are high during thermal stratification, so photosynthesis may represent a major source of oxygen during this period. Oxygen supersaturation in the euphotic zone can occur during periods of high photosynthesis.

2.3.3 PLANKTON

Phytoplankton influence dissolved oxygen and suspended solids concentrations, transparency, taste and odor, aesthetics, and other factors that affect reservoir uses and water quality objectives. Phytoplankton are a primary source of organic matter production and form the base of the autochthonous food web in many reservoirs since fluctuating water levels may limit macrophyte and periphyton production. Phytoplankton can be generally grouped as diatoms, green algae, cyanobacteria, or cryptomonad algae. Chlorophyll *a* represents a common variable used to estimate phytoplankton biomass.

Seasonal succession of phytoplankton species is a natural occurrence in reservoirs. The spring assemblage is usually dominated by diatoms and cryptomonads. Silica depletion in the photic zone and increased settling as viscosity decreases because of increased temperatures usually result in green algae succeeding the diatoms. Decreases in nitrogen or a decreased competitive advantage for carbon at higher pH may result in cyanobacteria succeeding the green algae during summer and fall. Diatoms generally return in the fall, but cyanobacteria, greens, or diatoms may cause algae blooms following fall turnover when hypolimnetic nutrients are mixed throughout the water column. The general pattern of seasonal succession of phytoplankton is fairly constant from year to year. However, hydrologic variability, such as increased mixing and delay in the onset of stratification during cool, wet spring periods, can maintain diatoms longer in the spring and shift or modify the successional pattern of algae in reservoirs.

Phytoplankton grazers can reduce the abundance of algae and alter their successional patterns. Some phytoplankton species are consumed and assimilated more readily and are preferentially selected by consumers. Single-celled diatom and green algae species are readily consumed by zooplankton, while filamentous cyanobacteria are avoided by zooplankter's. Altering the fish population can result in a change in the zooplankton population that can affect the phytoplankton population.

2.3.4 ORGANIC CARBON AND DETRITUS

Total organic carbon (TOC) is composed of dissolved organic carbon (DOC) and particulate organic carbon (POC). Detritus represents that portion of the POC that is nonliving. Nearly all the TOC of natural waters consists of DOC and detritus, or dead POC. The processes of decomposition and consumption of TOC are important in reservoirs and can have a significant effect on water quality.

DOC and POC are decomposed by microbial organisms. This decomposition exerts an oxygen demand that can remove dissolved oxygen from the water column. During stratification, the metalimnion and hypolimnion become relatively isolated from sources of dissolved oxygen, and depletion can occur through organic decomposition. There are two major sources of this organic matter: allochthonous (i.e., produced outside the reservoir and transported in) and autochthonous (i.e., produced within the reservoir). Allochthonous organic carbon in small streams may be relatively refractory since it consists of decaying terrestrial vegetation that has washed or fallen into the stream. Larger rivers, however, may contribute substantial quantities of riverine algae or periphyton that decompose rapidly and can exert a significant oxygen demand. Autochthonous sources include dead plankton settling from the mixed layers and macrophyte fragments and periphyton transported from the littoral zone. These sources are also rapidly decomposed.

POC and DOC absorbed onto sediment particles may serve as a major food source for aquatic organisms. The majority of the phytoplankton production enters the detritus food web with a minority being grazed by primary consumers (USACE, 1987). While autochthonous production is important in reservoirs, typically as much as three times the autochthonous production may be contributed by allochthonous material (USACE, 1987).

2.4 BOTTOM WITHDRAWAL RESERVOIRS

Bottom withdrawal structures are located near the deepest part of a reservoir. Bottom withdrawal removes hypolimnetic water and nutrients and may promote movement of interflows or underflow into the hypolimnion. They release cold water from the deep portion of the reservoir; however, this water may be hypoxic or anoxic during periods of stratification. Bottom outlets can cause density interflows or underflows (e.g., flow laden with sediment or dissolved solids) through the reservoir and generally provide little or no direct control over release water quality.

3 MAINSTEM SYSTEM WATER QUALITY MONITORING

3.1 MAINSTEM SYSTEM RESERVOIRS

3.1.1 LONG-TERM, FIXED-STATION AMBIENT MONITORING

Long-term, fixed-station ambient water quality monitoring has occurred at the six Mainstem System reservoirs (i.e., Fort Peck, Garrison, Oahe, Big Bend, Fort Randall, and Gavins Point) for the past 30 years. Recent ambient monitoring conducted by the District at the Mainstem System reservoirs included monthly (i.e., May through September) water quality monitoring at a near-dam, deepwater site. At Garrison, Fort Peck, Oahe, and Fort Randall Reservoirs, additional long-term ambient sites were added, respectively, in 2006, 2007, 2008, and 2009. At Lake Sakakawea, the added sites included three reservoir deepwater locations (Beulah Bay, RM1412; Deepwater Bay, RM1445; and New Town, RM1481) and one inflow location (Missouri River near Williston, ND, RM1553). At Fort Peck Reservoir, the added sites included two reservoir deepwater locations (Hell Creek Bay, RM1805 and Rock Creek Bay, upper reaches of Dry Creek Arm) and one inflow location (Missouri River near Landusky, MT, RM1921). At Lake Oahe, the added sites included four reservoir deepwater locations (Cheyenne River, RM1110; Whitlocks Bay, RM11153; Mobridge, RM1196; and Beaver Creek RM1256) and one inflow location (Missouri River at Bismarck, ND, RM1315). At Lake Francis Case, the added sites included three reservoir deepwater locations (Platte Creek, RM911; Elm Creek, RM940; and Chamberlain, RM968). Water quality monitoring included field measurements and collection of water samples for analytical analysis. Field measurements included surface water transparency (i.e., Secchi depth) and measuring temperature, dissolved oxygen, pH, conductivity, oxidation-reduction potential (ORP), turbidity, and chlorophyll at 1-meter increments from the reservoir surface to the bottom. Near-surface and near-bottom grab samples were collected and delivered to the laboratory where they were analyzed for various physicochemical and biological constituents.

3.1.2 BACTERIA MONITORING AT SWIMMING BEACHES

The District has cooperated with the Nebraska Department of Environmental Quality (NDEQ) to monitor bacteria levels present at swimming beaches at the Gavins Point project over the past 5 years. Five swimming beaches on Lewis and Clark Lake and one on Lake Yankton were monitored. Weekly grab samples were collected from May through September and analyzed for fecal coliform and *E. coli* bacteria and the cyanobacteria toxin microcystin. The bacteria monitoring was conducted to meet a 6-hour holding time for collected samples.

3.1.3 INTENSIVE WATER QUALITY SURVEYS

3.1.3.1 Lake Sharpe and Lewis and Clark Lake

The District completed the second year of planned 3-year intensive water quality surveys at Lake Sharpe and Lewis and Clark Lake in 2009. The monitoring objectives of the intensive surveys were to collect water quality data to spatially describe water quality conditions present in the reservoirs during the summer and to collect information to facilitate future application of the CE-QUAL-W2 hydrodynamic and water quality model. As part of the intensive surveys, five reservoir sites and one or two inflow sites were monitored. The five reservoir sites at Lake Sharpe were relatively equally spaced in deepwater areas from Big Bend Dam to near Pierre, SD. One inflow site was located on the Bad River and was meant to represent water quality conditions of water flowing into Lake Sharpe. The five reservoir sites at Lewis and Clark Lake were relatively equally spaced in deepwater areas from Gavins Point Dam to near

Springfield, SD. Inflow sites located on the Niobrara and Missouri Rivers were meant to represent water quality conditions of water flowing into Lewis and Clark Lake. At both Lake Sharpe and Lewis and Clark Lake, the monitored discharge of the upstream dams (i.e., Oahe and Fort Randall Dams) was taken to represent the water quality conditions of the inflowing Missouri River. Monthly samples at the reservoir and inflow sites were collected during June through September.

Water quality monitoring at the reservoir sites included field measurements for depth profiling and water transparency and collection of near-surface and near-bottom water samples for laboratory analysis. Monitoring at the inflow site included field measurements and collection of a near-surface water sample for laboratory analysis. Reservoir depth profiles in 1-meter increments were recorded for temperature, dissolved oxygen, pH, conductivity, ORP, turbidity, and chlorophyll. These same field measurements were taken at the inflow sites. Near-surface and near-bottom grab samples were analyzed for various physical, inorganic, nutrient, organic, and biological constituents.

3.2 MAINSTEM SYSTEM POWERPLANTS

As part of the operation of the Mainstem System powerplants, water is drawn from the intake structure of each dam and piped through the powerplant in a "raw water" supply line that is tapped for various uses. The "raw water" supply line is an open-ended, flow-through system. A monitoring station, that measures water quality conditions of water drawn from near the start of the "raw water" supply line, has been irregularly maintained at each of the powerplants in the past. Recent water quality monitoring has consisted of year-round, hourly measurements of temperature and dissolved oxygen through the use of a data-logger. Monthly grab samples (year-round) have also been collected and analyzed for various physical, inorganic, nutrient, and organic constituents. The rate of dam discharge when water quality monitoring occurred was determined from powerplant records. The water quality conditions measured in the "raw water" supply lines of the Mainstem System powerplants are believed to represent the water quality conditions present in the reservoirs near the dam intakes and in the tailwaters (i.e., Missouri River) immediately downstream of the dam.

3.3 MISSOURI RIVER FROM FORT RANDALL DAM TO RULO, NE

Since 2003, the District has cooperated with the State of Nebraska (NDEQ) to monitor ambient water quality conditions along the Missouri River from Fort Randall Dam to Rulo, Nebraska. Fixed-station monitoring has occurred at the following ten sites: Fort Randall Dam tailwaters; near Verdel, NE; near Niobrara, NE; Gavins Point Dam tailwaters; near Maskell, NE; near Ponca, NE; at Decatur, NE; at Omaha, NE; at Nebraska City, NE; and at Rulo, NE. Water quality monitoring consisted of collecting monthly near-surface grab samples year-round. The grab samples were collected from the bank in an area of fast current. The collected grab samples were analyzed for various physicochemical and biological constituents. Field measurements taken at the time of sample collection included temperature, pH, dissolved oxygen, conductivity, ORP, and turbidity.

3.4 MAINSTEM SYSTEM ANCILLARY LAKES – LAKE YANKTON, LAKE POCASSE, AND LAKE AUDUBON

Lake Yankton, Lake Pocasse, and Lake Audubon are ancillary lakes to the Mainstem System reservoirs located respectively at the Gavins Point, Oahe, and Garrison projects. Water quality monitoring at these three lakes has been sporadic in the past. The Omaha District initiated ambient water quality monitoring at the lakes in 2006 as part of a 3-year rotational monitoring cycle. All three lakes were monitored in 2009. Monitoring at the three lakes included monthly monitoring (May through September) at a near-dam deepwater location. The monitoring includes field measurements for depth profiling and water transparency and collection of near-surface and near-bottom water samples for

laboratory analysis. Depth profiles include measuring temperature, dissolved oxygen, pH, conductivity, ORP, turbidity, and chlorophyll in 1-meter increments. Near-surface and near-bottom grab samples are analyzed for various physical, inorganic, nutrient, organic, and biological constituents.

4 WATER QUALITY ASSESSMENT METHODS

4.1 EXISTING WATER QUALITY

For the purposes of this report, existing water quality is defined as water quality conditions that occurred during the past 5 years (i.e., 2005 through 2009). Water quality monitoring conducted during this period was used to describe existing water quality conditions.

4.1.1 STATISTICAL SUMMARY AND COMPARISON TO APPLICABLE WATER QUALITY STANDARDS CRITERIA

Statistical analyses were performed on the water quality monitoring data collected at the Mainstem System reservoirs (including inflow and outflow sites), powerplants, on the Missouri River, and at the Mainstem System ancillary lakes. Descriptive statistics were calculated to describe central tendencies and the range of observations in existing water quality. Monitoring results were compared to applicable water quality standards criteria established by the appropriate States pursuant to the Federal Clean Water Act. Tables were constructed that list the parameters measured; number of observations; and the mean, median, minimum, and maximum of the data collected. The constructed Tables also list the water quality standards criteria applicable to the individual parameters and the frequency that these criteria were not met.

4.1.2 SPATIAL VARIATION IN WATER QUALITY CONDITIONS

4.1.2.1 Longitudinal Variation

4.1.2.1.1 Reservoir Contour Plots

Longitudinal contour plots were developed for all six Mainstem System reservoirs. Contour plots were constructed for temperature, dissolved oxygen, and turbidity from depth-profile measurements collected along the length of the reservoirs. The longitudinal contour plots were constructed using the "Hydrologic Information Plotting Program" included in the "Data Management and Analysis System for Lakes, Estuaries, and Rivers" (DASLER-X) software developed by HydroGeoLogic Inc. (HydroGeoLogic Inc., 2005).

4.1.2.1.2 Reservoir Box Plots

Longitudinal box plots were developed for all six Mainstem System reservoirs from measurements collected along the length of the reservoir. When significant variation in measured parameters was observed along the length of the reservoir, box plots were constructed to display longitudinal variation.

4.1.2.1.3 Lower Missouri River Box Plots

Longitudinal box plots were constructed for the lower Missouri River from Gavins Point Dam to Rulo, NE. The box plots were constructed from the water quality monitoring conducted in cooperation with the NDEQ during the period 2005 through 2009. The box plots are oriented to display the measured change in selected water quality parameters along the Missouri River downstream of Gavins Point Dam.

4.1.2.2 Vertical Variation in Lake Water Quality

Depending on bathymetry and location, lakes can experience thermally-induced density stratification in the summer. This can lead to significant vertical water quality variation if anoxic or near-anoxic conditions develop in the hypolimnion.

4.1.2.2.1 Summer Depth-Profile Plots

Measured water temperature and dissolved oxygen depth profiles were plotted for the Mainstem System reservoirs and Mainstem System ancillary lakes. The plotted depth profiles were measured at the near-dam, deepwater ambient monitoring location. Depth profiles measured in the months of July, August, and September over the past 5 years were plotted. The plots were reviewed to assess the occurrence of thermal stratification and hypolimnetic dissolved oxygen degradation.

4.1.2.2.2 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

The variation of selected parameters with depth was evaluated by comparing paired near-surface and near-bottom collected samples. The compared paired samples were collected at the near-dam, deepwater monitoring location over the past 5 years. The parameters compared included water temperature, dissolved oxygen, ORP, pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen, total ammonia, and total phosphorus. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements, and a paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$).

4.1.3 TEMPORAL VARIATION IN WATER QUALITY CONDITIONS

4.1.3.1 Time Series Plots of Mean Daily Water Temperatures Measured in the Missouri River Upstream and Downstream of the Mainstem System Reservoirs

Annual seasonal time series plots of mean daily water temperatures measured in the Missouri River immediately upstream and downstream of the Mainstem System reservoirs were constructed to display temporal and spatial variation. These plots also give an indication of how the thermal regime of the Missouri River is impacted by the reservoir.

4.1.3.2 Time-Series Plots of Flow, Water Temperature, and Dissolved Oxygen of Water Discharged through the Mainstem System Dams

Time series plots were prepared for water quality conditions monitored at the Missouri River Mainstem System powerplants during the 5-year period 2005 through 2009. Semi-annual plots of hourly water temperature, dissolved oxygen, and dam discharge were constructed. Water temperature and dissolved oxygen plots represent monitoring of water drawn from the “raw water” supply line in each powerplant.

4.1.4 TROPHIC STATUS

A Trophic State Index (TSI) was calculated, as described by Carlson (1977). TSI values were determined from Secchi depth transparency, total phosphorus, and chlorophyll *a* measurements. Values for these three parameters were converted to an index number ranging from 0 to 100 according to the following equations:

$$\text{TSI(Secchi Depth)} = \text{TSI(SD)} = 10[6 - (\ln SD/\ln 2)]$$
$$\text{TSI(Chlorophyll } a) = \text{TSI(Chl)} = 10[6 - ((2.04\text{-}0.68 \ln Chl)/\ln 2)]$$
$$\text{TSI(Total Phosphorus)} = \text{TSI(TP)} = 10[6 - (\ln (48/TP)/\ln 2)]$$

Accurate TSI values from total phosphorus depend on the assumptions that phosphorus is the major limiting factor for algal growth and that the concentrations of all forms of phosphorus present are a function of algal biomass. Accurate TSI values from Secchi depth transparency depend on the assumption that water clarity is primarily limited by phytoplankton biomass. Carlson indicates that the chlorophyll TSI value may be a better indicator of a lake's trophic conditions during mid-summer when algal productivity is at its maximum, while the total phosphorus TSI value may be a better indicator in the spring and fall when algal biomass is below its potential maximum. Calculation of TSI values from data collected from a lake's epilimnion during summer stratification provide the best agreement between all of the index parameters and facilitate comparisons between lakes. A TSI average value, calculated as the average of the three individually determined TSI values, is used by the District as an overall indicator of a reservoir's trophic state. The District uses the criteria defined in Table 4-1 for determining lake trophic status from TSI values.

Table 4-1. Lake trophic status based on calculated TSI values.

TSI	Trophic Condition
0-35	Oligotrophic
36-50	Mesotrophic
51-55	Moderately Eutrophic
56-65	Eutrophic
66-100	Hypereutrophic

4.1.5 MAINSTEM SYSTEM RESERVOIR PHYTOPLANKTON COMMUNITY

Assessment of the phytoplankton community was based on grab samples that were analyzed by a contract laboratory. Laboratory analyses consisted of identification of phytoplankton taxa to the lowest practical level and quantification of taxa biovolume. These results were used to determine the relative abundance of phytoplankton taxa at the division level based on the measured biovolumes.

4.1.6 IMPAIRMENT OF DESIGNATED WATER QUALITY-DEPENDENT BENEFICIAL USES

Water quality-dependent beneficial uses are designated to waterbodies in State water quality standards and criteria are defined to protect these uses. Water quality data collected by the District during the 5-year period 2005 through 2009 were assessed to determine if water quality conditions were impairing the designated beneficial uses. These data were assessed using the methodologies defined by the appropriate States in developing their latest Integrated Water Quality Reports pursuant to the Federal Clean Water Act. It is noted that the "official" determination of whether water quality-dependent beneficial uses are impaired, pursuant to the Federal Clean Water Act, is by the States pursuant to their Section 305(b) and Section 303(d) assessments compiled in their biennial Integrated Water Quality Reports (See Table 1-3).

4.1.6.1 Montana Assessment Methodologies

The State of Montana requires that beneficial use support determinations be based on sufficient and credible data. Once sufficient and credible data are established, use support determinations are made based on defined assessment criteria (MDEQ, 2006). Assessment criteria for aquatic life, drinking water, and recreation use support applicable to water quality monitoring data collected by the District are given in Table 4-2, Table 4-3, and Table 4-4.

Table 4-2. Aquatic life use support assessment criteria defined by Montana and applicable to data collected by the District.

Data Type	Beneficial Use Impairment: Unimpaired or Least Impaired	Beneficial Use Impairment: Moderately Impaired	Beneficial Use Impairment: Severely Impaired
Chemical Toxicants (i.e., Trace Metals and Ammonia)	• No exceedance of acute water quality standard. • Exceedances of chronic water quality standard ≤10% (no more than once for one parameter in a 3-year period when measurements were taken at least 4 times/year).	• Exceedances of acute water quality standard 1 to 25%. • Exceedances of chronic water quality standard 11 to 50%. • Exceedances of chronic water quality standard 1 to 10% of a "large" data set.	• Exceedances of acute water quality standard >25%. • Exceedances of chronic water quality standard >50%. • Exceedances of chronic water quality standard >10% of a "large" data set.
Trophic Status	Trophic status is similar to reference conditions.	Trophic status exceeds reference conditions.	Trophic status is hypereutrophic.
Chemistry (i.e., Nutrients, D.O., pH, TSS, Turbidity, Temp.)	Exceedances of water quality standard ≤10% of a "large" data set.	Exceedances of water quality standard 11 to 25% of a "large" data set.	Exceedances of water quality standard >25% of a "large" data set.
Nutrients	Nutrient concentrations are similar to reference conditions.	Nutrient concentrations are moderately higher than reference conditions.	Nutrient concentrations are substantially higher then reference conditions.
Biological Assemblage (i.e., Phytoplankton)	Data indicate functioning sustainable biological assemblage (>75% of reference condition).	Data indicate moderate impairment (25 to 75% of reference condition).	Data indicate severe impairment (<25% of reference condition).
Chlorophyll a	The chlorophyll levels are similar to reference conditions.	The chlorophyll level is moderately higher than reference condition.	The chlorophyll level is substantially greater than reference condition

Table 4-3. Drinking water use support assessment criteria defined by Montana and applicable to data collected by the District.

Data Type	Beneficial Use Impairment: Unimpaired or Least Impaired	Beneficial Use Impairment: Moderately Impaired	Beneficial Use Impairment: Severely Impaired
Chemistry (i.e., Inorganics, Organics)	No human health standard exceedances.	Not applicable.	Exceedance of human health standards.

Table 4-4. Recreation use support assessment criteria defined by Montana and applicable to data collected by the District.

Data Type	Beneficial Use Impairment: Unimpaired or Least Impaired	Beneficial Use Impairment: Moderately Impaired	Beneficial Use Impairment: Severely Impaired
Algae, Toxins, etc.	There are no excessive algae blooms, turbidity, odor, toxins, etc.; similar to reference conditions.	Excessive algae blooms, turbidity, odor, toxins, etc. moderately restrict swimming or boating.	Swimming or boating severely inhibited by excessive algae blooms, pathogens, turbidity, odor, toxins, etc.
Chlorophyll a	The benthic chlorophyll level is similar to reference condition; or the chlorophyll is <50 mg/m^2.	The benthic chlorophyll level moderately exceeds reference condition; or the chlorophyll is 50 to 100 mg/m^2.	The benthic chlorophyll level greatly exceeds reference condition; or the chlorophyll is >100 mg/m^2.

4.1.6.2 Nebraska Assessment Methodologies

4.1.6.2.1 Assessment of Physicochemical Data

Nebraska water quality standards define acute and chronic numeric criteria for the protection of aquatic life and maximum criteria for the protection of public drinking and agricultural water supplies. Nebraska deems a designated use to be impaired if measured water quality conditions indicate that numeric criteria are exceeded more than 10 percent of the time over an assessed 5-year period (NDEQ, 2007). To address the uncertainty associated with water quality data, the application of the 10 percent exceedance criterion is based on the number of measurements for the appropriate water quality criteria. Table 4-5 gives the Nebraska assessment measures regarding sample size and the number of exceedances that indicate an impaired use (i.e., 10% exceedance) at a 90% confidence level (i.e., $\alpha = 0.10$).

Table 4-5. State of Nebraska Assessment Measures for Sample Size and Number of Exceedances Required to Determine an Impaired Use (i.e., 10% Exceedance).

Sample Size (n)	Number of Observations Exceeding a Criterion Required to Define an Impaired Use	Sample Size (n)	Number of Observations Exceeding a Criterion Required to Define an Impaired Use
<12	3	56 - 63	10
12 – 18	4	64 - 71	11
19 - 25	5	72 - 79	12
26 - 32	6	80 - 88	13
33 - 40	7	89 - 96	14
41 - 47	8	97 - 100	15
48 - 55	9	>100	Not Defined

4.1.6.2.2 Assessment of Fecal Coliform and *E. coli* Bacteria Data

Table 4-6 summarizes the Nebraska measures for the assessment of the Primary Contact Recreation Beneficial Use using fecal coliform and *E. coli* bacteria data.

Table 4-6. State of Nebraska measures for the assessment of the Primary Contact Recreation Beneficial Use using fecal coliform and *E. coli* bacteria data.

Parameter	Water Quality Criteria (Geometric Mean)	Supported	Impaired
Fecal Coliform	≤ 200cfu/100ml	Season geometric mean ≤ 200cfu/100ml	Season geometric mean > 200cfu/100ml
E. coli	≤ 126cfu/100ml	Season geometric mean ≤ 126cfu/100ml	Season geometric mean > 126cfu/100ml

4.1.6.2.3 Assessment of Reservoir Sedimentation

It is the State of Nebraska's position that excess sediment delivered to a lake can cause several problems including "objectionable colors, turbidity, and deposits." Deposition of sediment can displace or eliminate fish spawning and rearing and other aquatic habitats. Also, the recreation area of a lake can be reduced or rendered undesirable. Nebraska uses two measurements to assess lake sedimentation regarding the use of aesthetics: impoundment volume loss and sedimentation rate. Both the lake volume loss and sedimentation rate are based on the "as-built" conditions of the lake. Table 4-7 summarizes the Nebraska criteria for the assessment of lakes regarding sedimentation.

Table 4-7. State of Nebraska measures for the assessment of lake sedimentation data.

Minimum Assessment Period	Supported	Impaired
≥5 Years	Volume loss < 25%, and Annual sedimentation rate ≤0.75%	Volume loss ≥ 25%, and Annual sedimentation rate >0.75%

4.1.6.2.4 Assessment of Reservoir Nutrient Data

Nebraska contends that excessive nutrient concentrations can promote adverse effects to water quality and biological populations within lakes. Some of these effects include reductions in dissolved oxygen, water clarity, biodiversity, and fish and wildlife habitat; and increases in bacteria concentrations, toxin mobility, ammonia toxicity, and in-lake filling. Nebraska uses the term "nutrients" to refer specifically to total nitrogen and total phosphorus. The presence of nitrogen and phosphorus do not directly impair uses; rather, the nutrients spur algal and other vegetative growth that causes use impairment from algal toxins, extreme diurnal pH fluctuations, and dissolved oxygen depletion. Table 4-8 summarizes the Nebraska measures for the assessment of lakes regarding nutrients.

Table 4-8. State of Nebraska measures for the assessment of lakes regarding nutrients.

Beneficial Use	Parameter 1	Assessment 1	Parameter 2	Assessment Value
Aesthetics	Chlorophyll *a*	Growing Season Avg. > Site-Specific Criterion	Total Nitrogen or Total Phosphorus	Growing Season Avg. > Site-Specific Criteria
Aesthetics	Microcystin	> 20 ug/l	-----	-----
Aquatic Life	pH	<6.5 or > 9.0	Chlorophyll *a*	Growing Season Avg. > Site-Specific Criterion
Aquatic Life	Dissolved Oxygen	< Aquatic Life Criteria	Chlorophyll *a*	Growing Season Avg. > Site-Specific Criterion

4.1.6.3 <u>North Dakota Assessment Methodologies</u>

Water quality standards are the fundamental benchmarks North Dakota uses to assess surface water quality and determine beneficial use impairment status. North Dakota requires that beneficial use assessments be based on sufficient and credible data. The State criteria for sufficient and credible chemical, physical, and biological data are given in Table 4-9.

4.1.6.3.1 Assessment of Beneficial Use Support for Aquatic Life Based on Physicochemical Data

In general, aquatic life use determinations utilizing chemical data are based on the number of exceedances of the current State water quality standards criteria for dissolved oxygen, pH, and temperature; and on the number of exceedances of the acute or chronic standards for ammonia, aluminum, arsenic, cadmium, chromium, copper, cyanide, lead, nickel, selenium, silver, and zinc. The acute and chronic water quality standards criteria for trace metals are expressed as total recoverable metals and not as dissolved metals. However, where dissolved metals data are available, use support assessments are made by applying the dissolved metals data to the water quality standards criteria expressed as the total recoverable fraction. Table 4-10 gives the use support decision criteria that North Dakota uses to assess aquatic life use based on physicochemical data.

Table 4-9. State of North Dakota criteria for determining if data are sufficient and credible data for beneficial use impairment assessments.

• Data collection and analysis followed known and documented quality assurance/quality control procedures.
• Water column chemical or biological data are 10 years old or les for rivers, streams, lakes, and reservoirs; unless there is adequate justification to use older data (e.g., land use, watershed, or climatic conditions have not changed. Data for all 10 years of the period are not required to make an assessment.
• There are a minimum of 10 chemical samples collected in the 10-year period for rivers and streams. The 10 samples may range from one sample collected in each of 10 years or 10 samples collected all in 1 year.
• There should be a minimum of two samples collected from lakes or reservoirs collected during the growing season, May through September. The samples may consist of two samples collected the same year or samples collected in separate years.
• For all criteria that are expressed as a 30-day arithmetic average (e.g., chloride, sulfate, etc.) a minimum of four daily samples must be collected during any consecutive 30-day period. Samples collected during the same day shall be averaged and treated as one daily sample.
• Data collection and analysis followed known and documented quality assurance/quality control procedures.
• There are situations where a single set of data is all that is needed to make a use support determination. For example, a single set of water chemistry data may be sufficient to establish that a waterbody is not supporting aquatic life use. In such situations where a single data set irrefutably proves that impairment exists, an impairment determination may be based on this "overwhelming evidence." Data cannot be overwhelming evidence unless the methods used for collection and analysis meets the most stringent standards for reliability and validity. It must be certain that the data are representative of actual current waterbody conditions. The data must be representative of the spatial extent of the waterbody and of relevant temporal patterns. Data more than 3 or 4 years old should not be used as overwhelming evidence unless there is a strong basis for concluding that conditions have not changed since the data were collected.

Table 4-10. Aquatic life use support decision criteria defined by North Dakota for physicochemical data.

Aquatic Life Use Support	Criteria for Determining Use Support
Full Support	• Dissolved oxygen (DO) and pH: DO criterion of 5 mg/l (daily minimum) and pH criteria of 7 and 9 S.U. (daily minimum and maximum) not exceeded or exceeded in <10% of the samples and there is no record of lethality to aquatic biota. • Temperature: Daily maximum criterion of 29.4°C (85°F) not exceeded. • Ammonia and other toxic pollutants (i.e., trace elements and organics): Acute or chronic criterion is not exceeded during any consecutive 3-year period.
Full Support but Threatened	• DO and pH: One or more criteria exceeded in 11 to 25% of the samples. • Temperature: Daily maximum criterion exceeded in <10% of the samples. • Ammonia and other toxic pollutants (i.e., trace elements and organics): Acute or chronic criterion exceeded once or twice during any consecutive 3-year period.
Non Support	• DO and pH: One or more criteria exceeded in >25% of the samples. • Temperature: Daily maximum criterion exceeded in >10% of the samples. • Ammonia and other toxic pollutants (i.e., trace elements and organics): Acute or chronic criterion exceeded three or more times during any consecutive 3-year period.

4.1.6.3.2 Assessment of Beneficial Use Support for Aquatic Life and Recreation Based on Lake Trophic Data

Trophic status is used to assess whether aquatic life and recreation use of a lake is impaired. Under the North Dakota use assessment methodology, it is assumed hypereutrophic lakes do not fully support a sustainable sport fishery and are limited in recreational uses, whereas mesotrophic lakes fully

support both aquatic life and recreation use. Eutrophic lakes may be assessed as fully supporting, fully supporting but threatened, or not supporting their uses for aquatic life or recreation. North Dakota further assesses eutrophic lakes based on: 1) the lake's water quality standards fishery classification; 2) information provided by North Dakota Game and Fish Department Fisheries Division staff, local water resource managers, and the public; 3) the knowledge of land use in the lake's watershed; and/or 4) the relative degree of eutrophication. For example, a eutrophic lake, which has a well-balanced sport fishery and experiences infrequent algal blooms, is assessed as fully supporting with respect to aquatic life and recreation use. A eutrophic lake, which experiences periodic algal blooms and limited swimming use, would be assessed as not supporting recreation use. A lake fully supporting its aquatic life and/or recreation use, but for which monitoring has shown a decline in its trophic status (i.e., increasing phosphorus concentrations over time), would be assessed as fully supporting but threatened.

Carlson's Trophic State Index (TSI) is used to assess lake trophic status. When conducting an aquatic life and recreation use assessment for a lake, the average TSI score should be calculated for each indicator (i.e., chlorophyll *a*, Secchi depth, and total phosphorus). If TSI scores for each indicator result in a different trophic status assessment, the assessment should be based first on the chlorophyll *a*, followed by the Secchi depth transparency. Only when there are not adequate chlorophyll *a* and/or Secchi depth data available to make an assessment should total phosphorus concentration data be used.

4.1.6.3.3 Assessment of Beneficial Use Support for Drinking Water

North Dakota's water quality standards define drinking water as "waters that are suitable for use as a source of water supply for drinking and culinary purposes, after treatment to a level approved by the North Dakota Department of Health". While most lakes and reservoirs are assigned this use, few currently are used as a drinking water supply; however, the District's Lake Sakakawea is used as a drinking water supply. Drinking water use is assessed by comparing ambient water quality data to the State water quality standards criteria for chloride, sulfate, nitrate, and to the defined human health criteria. The decision criteria used by North Dakota to make beneficial use determinations are given in Table 4-11.

Table 4-11. Drinking water use support decision criteria defined by North Dakota.

Aquatic Life Use Support	Criteria for Determining Use Support
Full Support	No exceedances of the water quality standard criterion for nitrate, one or fewer exceedances of the 30-day average criteria for chloride or sulfate, and no exceedances of any of the human health standards.
Full Support but Threatened	The fully supporting, but threatened use assessment designation is not applied to the drinking water use. Waters are either assessed as fully supporting or not supporting based on chemical data applied to the numeric standards.
Non Support	One or more exceedances of the water quality criterion for nitrate, two or more exceedances of the 30-day average criteria for chloride or sulfate, or one or more exceedances of any of the human health criteria.

4.1.6.4 South Dakota Assessment Methodologies

The State of South Dakota requires that beneficial use support determinations be based on sufficient and credible data. Data must meet QA/QC requirements that assure data are representative. The decision criteria regarding data age, sample size, and exceedances that the State of South Dakota uses to determine beneficial use support are given in Table 4-12, Table 4-13, and Table 4-14.

Table 4-12. Data age requirements specified by South Dakota to consider data representative of actual conditions.

Description	Criteria Used
CONVENTIONAL PARAMETRS (e.g., dissolved oxygen, total suspended solids, pH, temperature, fecal coliform bacteria, etc.) TOXIC PARAMETERS (e.g., metals, ammonia, etc.)	• STREAMS: Data must be less than 5 years old. • LAKES: Data collected after 1999. Unless there is justification that data is (or is not) representative of current conditions.
TOXIC PARAMETERS (e.g., metals, ammonia, etc.)	• STREAMS: At least one water quality sampling event.. • LAKES: At least one fish flesh sampling event.

Table 4-13. Sample size requirements specified by South Dakota to consider data representative of actual conditions.

Description	Criteria Used
CONVENTIONAL PARAMETERS (e.g., DO, TSS, pH, temperature, fecal coliform bacteria, etc.)	• STREAMS: At least 20 samples for any one parameter are usually required at any site. The sample threshold is reduced to 10 samples if >25% of samples exceed water quality standards criteria since impairment is more likely. In addition, the sample threshold is reduced to five samples if 100% of the samples indicate full or nonsupport for that parameter. • LAKES: Two separate years of samples for conventional and Trophic State Index (TSI) parameters. Must include at least one Secchi depth and chlorophyll *a* value. Sample dates must be between May 15 and September 15.
TOXIC PARAMETERS (e.g., metals, ammonia, etc.)	• STREAMS: At least one water quality sampling event.. • LAKES: At least one fish flesh sampling event.

Table 4-14. Decision criteria for beneficial use support determination identified by South Dakota.

Description	Use Support	Criteria
CONVENTIONAL PARAMETERS (e.g., DO, TSS, pH, temperature, fecal coliform bacteria, etc.)	Full Support	STREAMS: <10% of samples exceed criteria (<25% if less than 20 samples available). LAKES: <10% of surface samples (<25% if less than 20 samples available).
	Non Support	STREAMS: >10% of samples exceed criteria (>25% if less than 20 samples available). LAKES: >10% of surface samples (>25% if less than 20 samples available). If one surface exceedance was observed for water temperature, DO, or pH; lake profile data is used to make use support determination. Lakes are considered fully supporting the aquatic life beneficial use if profile data indicate a region within the water column where temperature, pH, and dissolved oxygen meet numeric water quality standards criteria. If a region does not exist, the lake is listed for the parameter in exceedance.

4.2 WATER QUALITY TRENDS

Surface water quality trends were assessed for water clarity (i.e. Secchi depth), total phosphorus, chlorophyll *a*, and calculated average TSI from monitoring results obtained at long-term, fixed-station ambient monitoring sites. Scatter plots were prepared by plotting the four parameters over the time period 1980 through 2009. A linear regression trend line was also plotted. Analysis of variance (ANOVA) was used to determine an R^2 value and to test for the significance ($\alpha = 0.05$) of a linear trend over time.

4.3 FISH TISSUE

Fish are capable of accumulating many toxic substances in excess of 1,000 times the concentrations found in surface waters. Subsequently, fish tissue analyses may provide information concerning the presence of toxicants in a waterbody that may not be detected through either water or sediment samples. Because of this, fish tissue monitoring is an excellent early indicator of potential toxic problems in surface waters. Different tissue types in fish (e.g., muscle, bone, organ, skin, adipose, etc.) tend to accumulate toxicants at different rates. Therefore, when used as an indicator, fish tissue analysis typically uses whole fish samples – a combination of all tissue types. The analysis of fish fillets for toxicants is typically used to determine the suitability of fish for human consumption. The public has expressed concerns on whether fish caught at District Projects are safe to consume. It is important that answers to public health concerns be based on substantiated knowledge of toxicants in fish fillets and the public health risks associated with measured toxicant concentrations. This type of information can be used by Tribes and States when considering the issuance of fish consumption advisories.

The District, at this time, does not collect fish tissue data at the Mainstem System Projects. However, all of the States in the District are currently implementing monitoring programs that include fish tissue sampling at the Mainstem System Projects. The District defers to the Tribes and States regarding ambient fish tissue monitoring and the issuance of fish consumption advisories. Advisories that have been issued by the appropriate Tribes and States and are in affect at the Mainstem System Projects are listed in Table 1-3.

5 MAINSTEM SYSTEM RESERVOIRS

5.1 BACKGROUND INFORMATION

The Mainstem System is comprised of six dams and reservoirs constructed by the Corps on the Missouri River and, where present, the free-flowing Missouri River downstream of the dams. The six dams and reservoirs in an upstream to downstream order are: Fort Peck Dam and Fort Peck Lake (MT), Garrison Dam and Lake Sakakawea (ND), Oahe Dam (SD) and Lake Oahe (ND and SD), Big Bend Dam and Lake Sharpe (SD), Fort Randall Dam and Lake Francis Case (SD), and Gavins Point Dam and Lewis and Clark Lake (NE and SD) (Figure 1-1). The six reservoirs impounded by the dams contain about 73.3 million acre-feet (MAF) of storage capacity and, at normal pool, an aggregate water surface area of about 1 million acres. Drought conditions in the upper Missouri River Basin in the early to mid-2000's reduced the water stored in the upper three Mainstem System reservoirs to record low levels. The water in storage at the all Mainstem System reservoirs at the end of 2009 (i.e., December 31, 2009) was 54.28 MAF, which is about 74 percent of the total Mainstem System storage volume. Table 5-1 gives selected engineering data for each of the six reservoirs

5.1.1 REGULATION OF THE MAINSTEM SYSTEM

The Mainstem System is a hydraulically and electrically integrated system that is regulated to obtain the optimum fulfillment of the multipurpose benefits for which the dams and reservoirs were authorized and constructed. The Congressionally authorized purposes of the Mainstem System are flood control, navigation, hydropower, water supply, water quality, irrigation, recreation, and fish and wildlife (including threatened and endangered species). The Mainstem System is operated under the guidelines described in the Missouri River Mainstem System Master Water Control Manual, (Master Manual) (USACE-RCC, 2006a). The Master Manual details regulation for all authorized purposes as well as emergency regulation procedures in accordance with the authorized purposes.

Mainstem System regulation is, in many ways, a repetitive annual cycle that begins in late winter with the onset of snowmelt. The annual melting of mountain and plains snow packs along with spring and summer rainfall produces the annual runoff into the Mainstem System. In a typical year, mountain snow pack, plains snow pack, and rainfall events respectively contribute 50, 25, and 25 percent of the annual runoff to the Mainstem System. After reaching a peak, usually during July, the amount of water stored in the Mainstem System declines until late in the winter when the cycle begins anew. A similar pattern may be found in rates of releases from the Mainstem System, with the higher levels of releases from mid-March to late-November, followed by low rates of winter discharge from late-November until mid-March, after which the cycle repeats.

To maximize the service to all of the authorized purposes, given the physical and authorization limitations of the Mainstem System, the total storage available in the Mainstem System is divided into four regulation zones that are applied to the individual reservoirs. These four regulation zones are: 1) Exclusive Flood Control Zone, 2) Annual Flood Control and Multiple Use Zone, 3) Carryover Multiple Use Zone, and 4) Permanent Pool Zone.

Table 5-1. Summary of selected engineering data for the Missouri River Mainstem System.

	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point
General						
Lake Name	Fort Peck Lake	Lake Sakakawea	Lake Oahe	Lake Sharpe	Lake Francis Case	Lewis and Clark Lake
River Mile (1960 Mileage)	1771.5	1389.9	1072.3	987.4	880.0	811.1
Total and Incremental Drainage Area (square miles)	57,500	181,400 123,900	243,490 62,900	249,330 5,840	263,480 145,150	279,480 16,000
Reservoir Length at Top of Carryover Multiple Use Pool (miles)	134	178	231	80	107	25
Shoreline Length at Top of Carryover Multiple Use Pool (miles)	1,520	1,340	2,250	200	540	90
Top Elevation of Carryover Multiple Use Pool (ft-msl)	2234.0	1837.5	1607.5	1422.0	1350.0	1208.0
Year Storage First Available for Regulation of Flows	1940	1955	1962	1964	1953	1955
Original "As-Built" Conditions (Year)	(1937)	(1953)	(1958)	(1963)	(1953)	(1955)
Surface Area of Carryover Multiple Use Pool (acres)	214,718	322,030	314,649	59,150	82,000	31,100
Capacity of Carryover Multiple Use Pool (acre-feet)	15,869,000	18,917,000	19,490,000	1,920,000	3,911,000	510,000
Mean Depth at top of Carryover Multiple Use Pool[(1)] (feet)	73.9	58.7	61.9	32.5	47.7	16.4
Most Recent Surveyed Conditions (Year)	(2007)	(1988)	(1989)	(1997)	(1996)	(2007)
Surface Area at top of Carryover Multiple Use Pool (acres)	210,700	307,400	312,100	59,700	76,700	26,900
Capacity of Carryover Multiple Use Pool (acre-feet)	14,788,000	18,110,000	18,834,000	1,738,000	3,124,000	393,000
Mean Depth at top of Multiple Use Pool[(1)] (feet)	70.2	58.9	60.3	29.1	40.7	14.6
Sediment Deposition to Top of Carryover Multiple Use Pool						
Surveyed Sediment Deposition[(2)] (acre-feet)	1,081,000	807,000	656,000	182,000	787,000	117,000
Years of Sediment Deposition[(3)] (Survey Year - "As-Built Year")	70	35	31	34	43	52
Annual Sedimentation Rate[(4)] (acre-feet/year)	15,443	23,057	21,161	5,353	18,302	2,250
Annual Rate of Volume Loss from "As-Built" Condition	0.10%	0.12%	0.11%	0.28%	0.47%	0.44%
Years from "As-Built" to 2009	72	56	51	46	56	54
Estimated Sediment Deposition (acre-feet) through 2009[(5)]	1,111,886	1,291,200	1,079,226	246,235	1,024,930	121,500
2009 Estimated Capacity of Carryover Multiple Use Pool[(6)] (acre-feet)	14,757,114	17,625,800	18,410,774	1,673,765	2,886,070	388,500
Estimated Carryover Multiple Use Pool Capacity Lost through 2009	7.0%	6.8%	5.5%	12.8%	26.27%	23.8%
Operational Details – Historic (1967 through 2009)						
Maximum Recorded Pool Elevation (ft-msl)	2251.6	1854.8	1618.7	1422.1	1372.2	1209.5
Minimum Recorded Pool Elevation (ft-msl)	2196.2	1805.8	1570.2	1414.9	1317.9	1199.8
Average Daily Pool Elevation (ft-msl)	2229.3	1834.5	1601.1	1420.4	1351.1	1206.8
Maximum Recorded Daily Inflow (cfs)	160,000	180,000	204,000	79,000	100,000	74,000
Maximum Recorded Daily Outflow (cfs)	35,400	65,200	59,000	74,300	67,500	70,100
Average Annual Inflow (ac-ft)	7,230,000	16,228,000	17,936,000	16,986,000	17,892,000	19,622,000
Average Annual Outflow (ac-ft)	6,640,000	15,299,000	17,032,000	16,811,000	17,627,000	19,528,000
Operational Details – Current (2009)						
Maximum Recorded Pool Elevation (ft-msl)	2221.1	1842.6	1613.9	1421.1	1358.4	1208.5
Minimum Recorded Pool Elevation (ft-msl)	2209.6	1823.3	1592.5	1419.6	1336.5	1204.5
Maximum Recorded Daily Inflow (cfs)	24,000	76,000	172,000	35,000	45,000	34,000
Maximum Recorded Daily Outflow (cfs)	7,200	16,900	36,200	38,100	32,400	31,500
Total Inflow (% of Average Annual)	6,575,000 ac-ft (91%)	15,423,000 ac-ft (95%)	17,355,000 ac-ft (97%)	11,786,000 (69%)	13,105,000 (73%)	14,820,000 (76%)
Total Outflow (% of Average Annual)	3,829,000 ac-ft (58%)	10,065,000 ac-ft (66%)	12,329,000 ac-ft (72%)	11,635,000 (69%)	12,968,000 (74%)	14,806,000 (76%)
Power Tunnel Entrance Invert Elevation	2095 ft-msl (65 feet above bottom)	1672 ft-msl (2 feet above bottom)	1525 ft-msl (110 feet above bottom)	1330 ft-msl (Bottom)	1229 ft-msl (2 feet above bottom)	1139.5 ft-msl (Bottom)

Note: All elevations given are in the NGVD 29 datum.

(1) Mean Depth to top of Carryover Multiple Use Pool = Capacity of Carryover Multiple Use Pool (divided by) Surface Area of Carryover Multiple Use Pool.

(2) Surveyed Sediment Deposition is for the capacity (ac-ft) below the top of the Carryover Multipurpose Use Pool = "As-Built" capacity of Carryover Multiple Use Pool (minus) most recent surveyed capacity of Carryover Multiple Use Pool.

(3) Years of Sediment Deposition = year of most recent survey (minus) the "as-built" year.

(4) Annual Sedimentation Rate (ac-ft/yr) = Survey Sediment Deposition / Years of Sediment Deposition.

(5) Estimated Sediment Deposition through 2009 = Annual Sedimentation Rate (times) Years from "As-Built" to 2009..

(6) Current Capacity of Carryover Multiple Use Pool (ac-ft) = "As-Built" Capacity of Carryover Multiple Use Pool (minus) Current Estimated Capacity of Carryover Multiple Use Pool.

5.1.1.1 Exclusive Flood Control Zone

Flood control is the only authorized purpose that requires empty space in the reservoirs to achieve the objective. A top zone in each Mainstem System reservoir is reserved for use to meet the flood control requirements. This storage space is used only for detention of extreme or unpredictable flood flows and is evacuated as rapidly as downstream conditions permit, while still serving the overall flood control objective of protecting life and property. The Exclusive Flood Control Zone encompasses 4.7 MAF and represents the upper 6 percent of the total Mainstem System storage volume. This zone, from 73.3 MAF down to 68.7 MAF, is normally empty. The four largest reservoirs, Fort Peck, Garrison, Oahe, and Fort Randall, contain 97 percent of the total storage reserved for the Exclusive Flood Control Zone.

5.1.1.2 Annual Flood Control and Multiple Use Zone

An upper "normal operating zone" is reserved annually for the capture and retention of runoff (normal and flood) and for annual multiple-purpose regulation of this impounded water. The Mainstem System storage capacity in this zone is 11.7 MAF and represents 16 percent of the total Mainstem System storage. This storage zone, which extends from 68.7 MAF down to 57.0 MAF, will normally be evacuated to the base of this zone by March 1 to provide adequate storage capacity for capturing runoff during the next flood season. On an annual basis, water will be impounded in this zone, as required to achieve the Mainstem System flood control purpose and also be stored in the interest of general water conservation to serve all the other authorized purposes. The evacuation of water from the Annual Flood Control and Multiple Use Zone is scheduled to maximize service to the authorized purposes that depend on water from the Mainstem System. Scheduling releases from this zone is limited by the flood control objective in that the evacuation must be completed by the beginning of the next flood season. This is normally accomplished as long as the evacuation is possible without contributing to serious downstream flooding. Evacuation is, therefore, accomplished mainly during the summer and fall because Missouri River ice formation and the potential for flooding from higher release rates limit release rates during the December through March period.

5.1.1.3 Carryover Multiple Use Zone

The Carryover Multiple Use Zone is the largest storage zone extending from 57.0 MAF down to 18.0 MAF, and represents 53 percent of the total Mainstem System storage volume. Serving the authorized purposes during an extended drought is an important regulation objective of the Mainstem System. The Carryover Multiple Use Zone provides a storage reserve to support authorized purposes during drought conditions. Providing this storage is the primary reason the upper three reservoirs of the Mainstem System are so large compared to other Federal water resource projects. The Carryover Multiple Use Zone is often referred to as the "bank account" for water in the Mainstem System because of its role in supporting authorized purposes during critical dry periods when the storage in the Annual Flood Control and Multiple Use Zone is exhausted. Only the reservoirs at Fort Peck, Garrison, Oahe, and Fort Randall have this storage as a designated storage zone. The three larger reservoirs (Fort Peck, Garrison, and Oahe) provide water to the Mainstem System during drought periods to provide for authorized purposes. The storage space assigned to this zone in Fort Randall Reservoir serves a different purpose. It is normally evacuated each year during the fall season to provide recapture space for upstream winter power releases. The recapture results in complete refill of Fort Randall Reservoir during the winter months. During drought periods, the three smaller projects (Fort Randall, Big Bend, and Gavins Point) reservoir levels are maintained at the same elevation they would be at if runoff conditions were normal.

5.1.1.4 Permanent Pool Zone

The Permanent Pool Zone is the bottom zone that is intended to be permanently filled with water. The zone provides for future sediment storage capacity and maintenance of minimum pool levels for power heads, irrigation diversions, water supply, recreation, water quality, and fish and wildlife. A drawdown into this zone will generally not be scheduled except in unusual conditions. The Mainstem System storage capacity in this storage zone is 18.0 MAF and represents 25 percent of the total storage volume. The Permanent Pool Zone extends from 18.0 MAF down to 0 MAF.

5.1.2 WATER CONTROL PLAN FOR THE MAINSTEM SYSTEM

Variations in runoff into the Mainstem System necessitates varied regulation plans to accommodate the multipurpose regulation objectives. The two primary high-risk flood seasons are the plains snowmelt and rainfall season extending from late February through April, and the mountain snowmelt and rainfall period extending from May through July. Also, the winter ice-jam flood period, which extends from mid-December through February, can be a high-risk flood period. The highest average power generation period extends from mid-April to mid-October, with high peaking loads during the winter heating season (mid-December to mid-February) and the summer air conditioning season (mid-June to mid-August). The power needs during the winter are supplied primarily with Fort Peck and Garrison Dam releases and the peaking capacity of Oahe and Big Bend Dams. During the spring and summer period, releases are normally geared to navigation and flood control requirements, and primary power loads are supplied using the four lower dams. During the fall when power needs diminish, Fort Randall is normally drawn down to permit generation during the winter period when Oahe and Big Bend peaking-power releases refill the reservoir. The normal 8-month navigation season extends from April 1 through November 30, during which time Mainstem System releases are increased to meet downstream target flows in combination with downstream tributary inflows. Winter releases after the close of the navigation season are much lower and vary depending on the need to conserve or evacuate storage volumes, downstream ice conditions permitting. Releases and pool fluctuations for fish spawning management generally occur from April 1 through June. Two threatened and endangered bird species, piping plover (*Charadrius melodus*) and least tern (*Sterna antillarum*), nest on “sandbar” areas from early May through mid-August. Other factors may vary widely from year to year, such as the amount of water-in-storage and the magnitude and distribution of inflow received during the coming year. All these factors will affect the timing and magnitude of Mainstem System releases. The gain or loss in the water stored at each reservoir must also be considered in scheduling the amount of water transferred between reservoirs to achieve the desired storage levels and to generate power. These items are continually reviewed as they occur and are appraised with respect to the expected range of regulation.

5.1.3 OCCURRENCE OF “TWO-STORY” FISHERIES

Fort Peck, Garrison, and Oahe Reservoirs maintain “two-story” fisheries that are comprised of warmwater and coldwater species. The ability of the reservoirs to maintain “two-story” fisheries is due to their thermal stratification in the summer into a colder bottom region and a warmer surface region. Warmwater species present in the reservoirs that are recreationally important include walleye (*Sander vitreus*), sauger (*Sander canadensis*), northern pike (*Esox lucius*), smallmouth bass (*Micropterus dolomieu*), catfish (*Ictalurus spp.*), and yellow perch (*Perca flavescens*). Coldwater species of recreational importance are the Chinook salmon (*Oncorhynchus tshawytscha*) and lake trout (*Salvelinus namaycush*). Chinook salmon are maintained in all three reservoirs through regular stocking, and a naturally-reproducing lake trout fishery is present in Fort Peck Reservoir. Other coldwater species present are rainbow smelt (*Osmerus mordax*) in Oahe and Garrison Reservoirs and lake cisco (*Coregonus artedi*) in Fort Peck Reservoir. Both these species are important forage fish that are utilized extensively by all recreational species in the respective reservoirs. Maintaining healthy populations of these coldwater forage fish are important to maintaining the recreational fisheries in the three reservoirs.

The occurrence of coldwater habitat in Fort Peck, Garrison, and Oahe Reservoirs is directly dependent on each reservoir's annual thermal regime. Early in the winter ice-cover period, the entire reservoir volume will be supportive of coldwater habitat. As the winter ice-cover period continues, lower dissolved oxygen concentrations will likely occur near the bottom as organic matter decomposes and reservoir mixing is prevented by ice cover. As dissolved oxygen concentrations in the near-bottom water fall below 5 mg/l, coldwater habitat will not be supported. During the spring isothermal period, water temperatures and dissolved oxygen levels in the entire reservoir volume will be supportive of coldwater habitat. During the early-summer warming period, the epilimnion will become non-supportive of coldwater habitat. During mid-summer when the reservoirs are experiencing maximum thermal stratification, water temperatures will only be supportive of coldwater habitat in the hypolimnion. Theoretically, coldwater habitat should remain stable during this period unless degradation of dissolved oxygen concentrations near the reservoir bottom becomes non-supportive of coldwater habitat. The most crucial period for the support of coldwater habitat in the three reservoirs is when they begin to cool in late summer. As the thermocline moves deeper, the volume of the coldwater hypolimnion will continue to decrease while the expanding epilimnion may not yet be cold enough to be supportive of coldwater habitat. At the same time, hypolimnetic dissolved oxygen concentrations are approaching their maximum degradation and low dissolved oxygen levels are moving upward from the reservoir bottom and pinching off coldwater habitat from below. This situation will continue to worsen until the epilimnion cools enough to be supportive of coldwater habitat. When fall turnover occurs, dissolved oxygen concentrations at all depths will be near saturation and supportive of coldwater habitat. However, depending on the conditions of the reservoir, the isothermal temperature at the beginning of fall turnover may not be supportive of all coldwater habitats. This situation will continue to occur until the isothermal temperature cools to a suitable temperature, at which time the entire reservoir volume will be supportive of coldwater habitat.

5.2 FORT PECK

5.2.1 BACKGROUND INFORMATION

5.2.1.1 Project Overview

Fort Peck Dam is located on the Missouri River at river mile (RM) 1771.5 in northeastern Montana, 17 miles southeast of Glasgow, MT. The closing of Fort Peck Dam in 1937 resulted in the formation of Fort Peck Reservoir (Fort Peck Lake). When full, the reservoir is 134 miles long, covers 246,000 acres, and has 1,520 miles of shoreline. Table 5-2 summarizes how the surface area, volume, mean depth, and retention time of Fort Peck Lake vary with pool elevations. Although still experiencing lower pool levels due to past drought conditions, the reservoir did recover to a pool elevation of 2221.1 at the end of December 2009. This is 11.1 feet higher than the reservoir was 1-year ago at the end of 2008. At a pool elevation of 2221.1 ft-msl, Fort Peck Lake is 12.9 feet below the top of the Carryover Multiple Use Zone (2234.0 ft-msl). Major inflow to the reservoir comes from the Missouri River with minor inflows coming from the Musselshell River and Big Dry Creek. Water discharged through Fort Peck Dam for power production is withdrawn from Fort Peck Lake at elevation 2095 ft-msl – approximately 65 feet above the reservoir bottom. Figure 5-1 shows a schematic drawing of the outlet works at Fort Peck Dam.

Fort Peck was authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Over the period 1967 through 2009, the five generating units at Fort Peck Dam have produced an annual average 1.052 million mega-watt hours (MWh) of electricity, which has a current revenue value of approximately $17 million. The ongoing drought in the western United States has curtailed releases and power production at the Mainstem System projects, including Fort Peck. Power production at the Fort Peck Dam generating

units averaged an annual 0.617 MWh over the 5-year period 2005 through 2009. Habitat for one endangered species, pallid sturgeon (*Scaphirhynchus albus*), occurs within the project area. The reservoir is used as a water supply by the town of Fort Peck, MT (RM1772 – penstock) and by individual cabins in the area. Fort Peck Lake is an important recreational resource and a major visitor destination in Montana.

5.2.1.2 Water Quality Standards Classifications and Section 303(d) Listings

5.2.1.2.1 Fort Peck Lake

The State of Montana has assigned Fort Peck Lake a B-3 classification in the State's water quality standards. As such, the reservoir is to be maintained suitable for drinking, culinary, and food processing purposes, after conventional treatment; bathing, swimming, and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply. Fort Peck Lake is not assigned a coldwater fishery use by the State in their water quality standards; however, the reservoir supports a stocked salmon fishery and a naturally reproducing lake trout and lake cisco fishery – all are considered coldwater species. Since a coldwater fishery is currently supported in Fort Peck Lake it is an existing use and must be protected pursuant to the Federal Clean Water Act and antidegradation policy provisions (40 CFR 131.3). Pursuant to Section 303(d) of the Federal CWA, Montana has placed Fort Peck Lake on the State's list of impaired waters citing impairment to the use of drinking water. The impairment of drinking water is attributed to the pollutants of lead and mercury. The identified sources of these pollutants are agriculture, abandoned mining, atmospheric deposition, and historic bottom deposits. The State of Montana has also issued a fish consumption advisory for Fort Peck Lake due to mercury concerns.

Table 5-2. Surface area, volume, mean depth, and retention time of Fort Peck Lake at different pool elevations based on 2007 survey.

Pool Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
2250	245,405	18,462,840	75.2	2.78
2245	237,605	17,253,500	72.6	2.60
2240	225,065	16,094,980	71.5	2.42
2235	213,025	15,000,180	70.4	2.26
2230	201,130	13,964,500	69.4	2.10
2225	188,765	12,991,390	68.8	1.96
2220	180,590	12,069,610	66.8	1.82
2215	171,930	11,188,080	65.1	1.68
2210	163,400	10,349,820	63.3	1.56
2205	154,773	9,554,578	61.7	1.44
2200	146,595	8,801,156	60.0	1.33
2195	138,081	8,090,417	58.6	1.22
2190	132,175	7,415,889	56.1	1.12
2185	126,146	6,769,319	53.7	1.02
2180	118,608	6,156,918	51.9	0.93
2175	111,285	5,582,093	50.2	0.84
2170	103,394	5,045,002	48.8	0.76
2165	95,316	4,549,151	47.7	0.69
2160	89,461	4,087,903	45.7	0.62

Average Annual Inflow (1967 through 2009) = 7.230 Million Acre-Feet
Average Annual Outflow: (1967 through 2009) = 6.640 Million Acre-Feet
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 2250-2246 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 2246-2234 ft-msl), Carryover Multiple Use Zone (elev. 2234-2160 ft-msl), and Permanent Pool Zone (elev. 2160-2030 ft-msl). All elevations are in the NGVD 29 datum.

Figure 5-1. **S**chematic drawing of the outlet works at Fort Peck Dam.

5.2.1.2.2 Missouri River Downstream of Fort Peck Dam

The Missouri River downstream of Fort Peck Dam has been designated a B-2 classification from the dam to the confluence of the Milk River, and a B-3 classification from the Milk River confluence to the Montana/North Dakota state line (Montana water quality standards). Both B-2 and B-3 waters are to be maintained suitable for drinking, culinary, and food processing purposes, after conventional treatment; bathing, swimming, and recreation; waterfowl and furbearers; and agricultural and industrial water supply. In addition, B-2 waters are to maintain growth and marginal propagation of salmonid fishes and associated aquatic life, and B-3 waters are to maintain growth and propagation of non-salmonid fishes and associated aquatic life. The river is used as a water supply by several towns along the reach. Pursuant to Section 303(d) of the Federal Clean Water Act, Montana has placed the Missouri River downstream of Fort Peck Dam on the State's list of impaired waters citing impairment to the uses of aquatic life support, coldwater fishery, and warmwater fishery due to the stressor of water temperature. No fish consumption advisory has been issued for the Missouri River downstream of Fort Peck Dam by the State of Montana.

The Assiniboine and Sioux Tribes of the Fort Peck Indian Reservation have developed water quality standards, approved by the U.S. Environmental Protection Agency, that are applicable to their tribal lands. This includes an area on the north side of the Missouri River downstream of Fort Peck Dam from the Milk River to Big Muddy Creek. The tribal water quality standards applicable to this reach of the Missouri River are comparable to the State of Montana's water quality standards.

5.2.1.3 Water Quality for the Enhancement of Pallid Sturgeon Populations in the Missouri River Downstream of Fort Peck Dam

One of the few remaining populations of pallid sturgeon occurs in the Missouri River between Fort Peck Dam and the headwaters of Lake Sakakawea. Individuals in this population also inhabit the

lower Yellowstone River. As such, this reach of the Missouri River has been identified as a priority recovery area for the pallid sturgeon (USFWS, 1993). It is believed that the building and operation of Fort Peck Dam and Reservoir have adversely impacted the pallid sturgeon in this reach of the Missouri River by regulating flows, lowering water temperatures, reducing sediment and nutrient transport, and increasing water clarity (USFWS, 2003).

Historically, the lower Missouri River in Montana was a turbid, warmwater environment with seasonally fluctuating flows. The sediment and turbidity of the water through these cycles contributed significantly to the evolution of the pallid sturgeon. The fish adapted to highly turbid and low visibility environments by physiologically evolving to enhance their ability to capture prey and avoid capture as juveniles and larvae in this low visibility environment. It is also believed that the pallid sturgeon adapted by developing spawning cues based on historical conditions in the river. The fish requires a spawning cue of suitable magnitude, duration, and timing to complete this life cycle element. It is believed that increasing flow and water temperature in the late spring is a primary factor for pallid sturgeon to initiate spawning.

Water temperature is believed to be a controlling factor on the pallid sturgeon in this reach of the Missouri River in regards to spawning cues and larval survival during the summer. Because Fort Peck Dam has a deepwater withdrawal from the reservoir, water temperature in the Missouri River downstream of the dam are appreciably colder than "pre-dam" conditions. A water temperature of around 18°C (64.4°F) is believed necessary to initiate a spawning response in pallid sturgeon. Additionally, a dramatic decline in water temperatures after spawning can affect larval pallid sturgeon development and likely adversely affect the production and availability of suitable forage (i.e., plankton and other invertebrate species) for the juvenile pallid sturgeon throughout the summer. Low water temperatures may induce mortality in young pallid sturgeon. With this in mind, a late-spring/early-summer water temperature of 18°C in the Missouri River at Frazer Rapids (approximately 25 miles downstream of Fort Peck Dam) has been identified as critical for pallid sturgeon spawning and recruitment in this reach of the river.

Fort Peck Dam and Reservoir is trapping sediment that historically moved down the Missouri River. It is also believed that the current colder water temperatures in the river downstream of the dam are likely suppressing production of plankton and other invertebrate organisms that contribute to turbidity of the water. The resulting clearer water is believed to adversely affect young pallid sturgeon by making them more vulnerable to sight-feeding predators and increasing competition for food by sight-adapted predators. In addition, adult fish may be adversely affected by the increased ability of prey to avoid capture in clearer water.

5.2.1.4 **Ambient Water Quality Monitoring**

The District has monitored water quality conditions at the Fort Peck Project since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow to and outflow from the reservoir. A 3-year intensive water quality survey was completed at the Fort Peck Project in 2006, and the findings of the intensive survey are available in the separate report, "Water Quality Conditions Monitored at the Corps' Fort Peck Project in Montana during the 3-Year period 2004 through 2006" (USACE, 2007a). Other recent water quality reports concerning the Fort Peck Project include: "Simulation of Fort Peck Lake Temperature Releases and Downstream Missouri River Temperatures" (USACE, 2007b), "Fort Peck Temperature Control Device Reconnaissance Study Fort Peck, Montana" (Tetra Tech, 2009), and "Application of the CE-QUAL-W2 Hydrodynamic and Water Quality Model to Fort Peck Reservoir, Montana (2009a). Figure 5-2 shows the location of sites at the Fort Peck Project that have been monitored by the District for water quality during the past 5 years (i.e., 2005 through 2009). The near-dam location (i.e., site FTPLK1772A) has been continuously monitored since 1980.

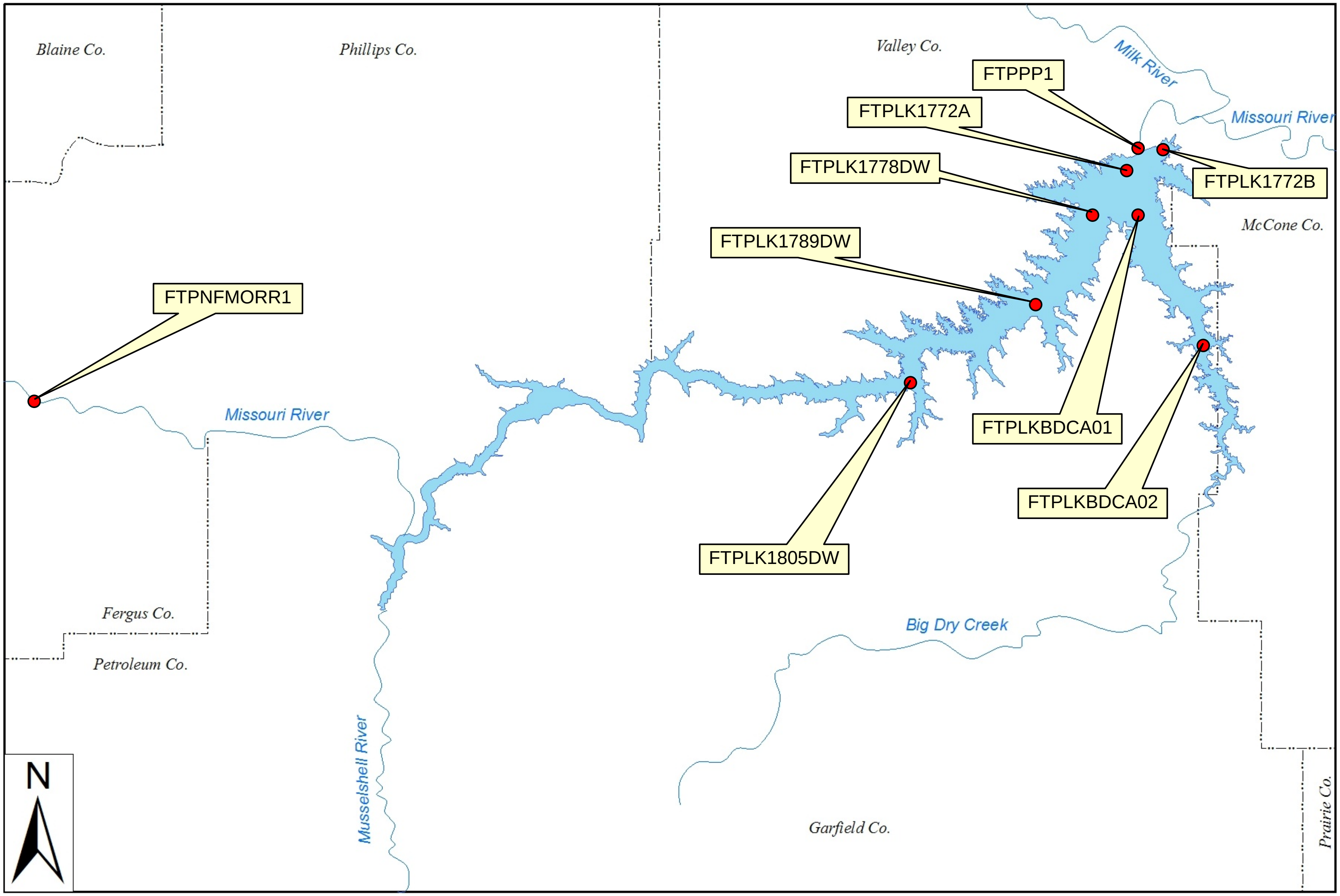

Figure 5-2. Location of sites where water quality monitoring was conducted by the District at the Fort Peck Project during the 5-year period 2005 through 2009.

5.2.2 WATER QUALITY IN FORT PECK LAKE

5.2.2.1 <u>Existing Water Quality Conditions</u>

5.2.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Fort Peck Lake at sites FTPLK1772A, FTPLK1778DW, FTPLK1789DW, FTPLK1805DW, FTPLKBDCA01, and FTPLKBDCA02 from May through September during the 5-year period 2005 through 2009 are summarized in Plate 1 through Plate 6. A review of these results found no significant water quality concerns. On a few occasions measured dissolved oxygen concentrations were below the water quality standards criterion of 5 mg/l for the protection of Class B-3 warmwater aquatic life in the mid-reaches of the Missouri River Arm (Plate 3 and Plate 4). The measured low dissolved oxygen concentrations occurred in the hypolimnion near the reservoir bottom during the later part of the summer thermal stratification period. The lowest dissolved oxygen concentration measured was 2.2 mg/l and occurred at site FTPLK1789DW on August 30, 2006.

5.2.2.1.2 Summer Thermal Stratification

5.2.2.1.2.1 Monthly Longitudinal Temperature Contour Plots

Summer thermal stratification of Fort Peck Lake during 2009 is described by longitudinal temperature contour plots based on depth-profile temperature measurements taken during June, July, August, and September (Plate 7 - Plate 10). The contour plots were constructed along two longitudinal axes; the Missouri River mainstem arm and the Big Dry Creek arm. As seen in Plate 7 through Plate 10, temperatures in Fort Peck Lake vary longitudinally from the dam to the Missouri River inflow and vertically from the reservoir surface to the bottom. The near-surface water in the upstream reach of the reservoir warms up sooner in the spring than the near-surface water near the dam (Plate 7 and Plate 8). By mid-summer a strong thermocline becomes established in the downstream reach of the reservoir, and the near-surface waters of the entire reservoir above the thermocline are a fairly uniform temperature (Plate 9). As the near-surface waters of the reservoir cool in the late summer, the thermocline moves deeper, and the wind-mixed upper waters are fairly uniform in temperature (Plate 10). The vertical variation in temperature is most prevalent in the deeper area of the reservoir towards the dam, where a strong thermocline becomes established during the summer. The shallower upper reaches of Fort Peck Lake do not exhibit much vertical variation of temperature during mid- to late summer, as wind action allows for complete mixing of the water column.

5.2.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Fort Peck Lake at the deep water area near the dam is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summer were compiled (Plate 11). The plotted depth-profile measurements indicate that a significant temperature-depth gradient occurs in Fort Peck Lake in the near-dam lacustrine area during the summer, and a thermocline becomes established at a depth of about 20 meters (Plate 11).

5.2.2.1.3 Summer Dissolved Oxygen Conditions

5.2.2.1.3.1 Monthly Longitudinal Dissolved Oxygen Contour Plots

Summer dissolved oxygen conditions in Fort Peck Lake during 2009 are described by the monthly longitudinal dissolved oxygen contour plots based on depth-profile temperature measurements taken in June, July, August, and September (Plate 12 - Plate 15). The contour plots were constructed

along two longitudinal axes; the Missouri River mainstem arm and the Big Dry Creek Arm. As seen in Plate 12 through Plate 15, dissolved oxygen conditions in Fort Peck Lake vary longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Dissolved oxygen levels below 5 mg/l first appeared near the reservoir bottom in the middle reaches of the Missouri River Arm in September (Plate 15). Near-bottom dissolved oxygen concentrations near the dam remained above 5 mg/l. The earlier occurrence of low dissolved oxygen concentrations in the near-bottom water of the middle reaches of Fort Peck Lake is attributed to the increased organic loading (allochthonous and autochthonous) in the transition zone of the reservoir and the lesser hypolimnetic volume available for assimilation of the oxygen demand. As this material decomposes, a "pool" of water with lower dissolved oxygen levels accumulates near the bottom in this area of the reservoir. Decomposition of autochthonous organic matter also occurs in the lacustrine zone and results in dissolved oxygen degradation as the summer progresses, although at a slower rate than what occurs in the transition zone. The recovery of near-bottom dissolved oxygen concentrations to saturation levels takes longer in the lacustrine zone nearer the dam because of the time needed for thermal stratification to breakdown and mixing within the water column to occur in the deeper water.

5.2.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Fort Peck Lake at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured over the past 5 years. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 16). Dissolved oxygen levels did not exhibit a large gradient with depth and tended toward an orthograde to slight clinograde vertical distribution (Plate 16). During the 5 years 2005 through 2009, monitored dissolved oxygen concentrations in the hypolimnion remained above 5 mg/l through the summer (Plate 1 and Plate 16).

5.2.2.1.4 Water Clarity

5.2.2.1.4.1 Secchi Transparency

Figure 5-3 displays a box plot of the Secchi depth transparencies measured at monitoring sites FTPLK1772A, FTPLK1805DW, and FTPLKBDCA02 during 2005 through 2009. Secchi depth transparency was observably lower in the upper reaches of both arms of the reservoir (i.e., sites FTPLK1805DW and FTPLKBDCA02) as compared to the near-dam conditions (i.e., site FTPLK1772A).

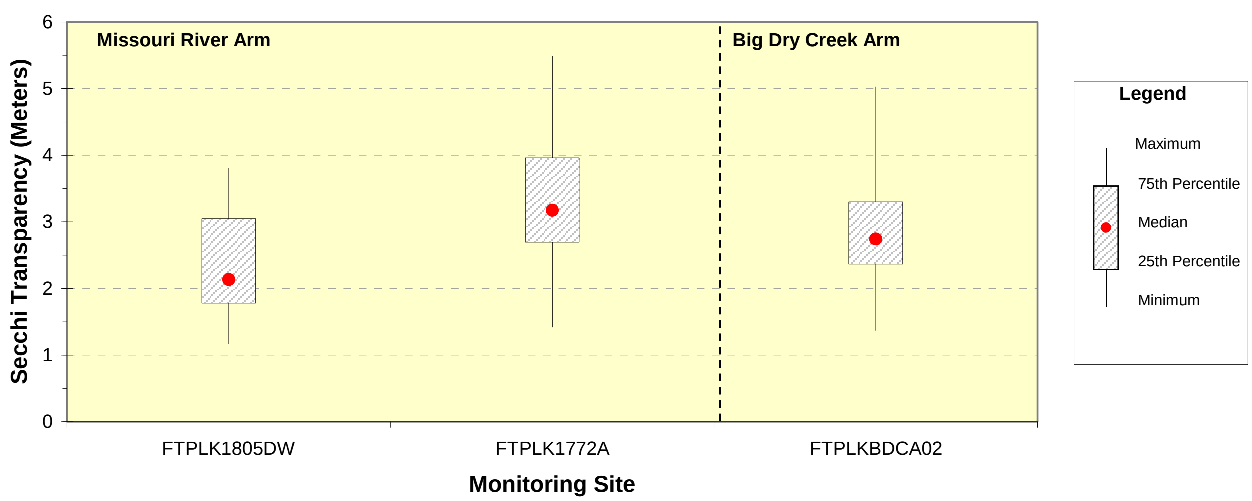

Figure 5-3. Box plot of Secchi transparencies measured in Fort Peck Lake during the 5-year period 2005 through 2000.

5.2.2.1.4.2 Turbidity

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level. Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. Given the low chlorophyll *a* concentrations monitored in Fort Peck Lake, turbidity in the reservoir appears to be largely due to suspended inorganic material. Monthly (i.e., June, July, August, and September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and, FTPNFMORR1 during 2009 (Plate 17 - Plate 20). As seen in the longitudinal contour plots, turbidity levels in Fort Peck Lake vary longitudinally from the dam to reservoir's upstream reaches. Turbidity levels are noticeably higher in the upstream reaches of the Missouri River Arm of the reservoir in the early summer as compared to the area near the dam. This is attributed to the turbid conditions of the inflowing Missouri River.

5.2.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Fort Peck Lake during the summer were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 2-meters of the reservoir bottom. The compared samples were collected at the near-dam site FTPLK1772A during the 5-year period 2005 through 2009. During the period a total of 19 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 21). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for all the assessed parameters except TOC, TKN, total ammonia, and total phosphorus. Parameters that were significantly lower in the near-bottom water of Fort Peck Lake included: water temperature ($p < 0.001$), dissolved oxygen ($p < 0.01$), and pH ($p < 0.001$). Parameters that were significantly higher in the near-bottom water included: ORP ($p < 0.001$) and alkalinity ($p < 0.01$).

5.2.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Fort Peck Lake were calculated from monitoring data collected during the 5-year period 2005 through 2009 (Table 5-3). The calculated TSI values indicate that the regions of the reservoir represented by the monitored sites are in a mesotrophic state.

Table 5-3. Mean Trophic State Index (TSI) values calculated for three sites on Fort Peck Lake based on monitoring conducted during the 5-year period 2005 through 2009.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
FTPLK1772A	44	52	47	48
FTPLK1805DW	48	52	51	50
FTPLKBDCA02	45	47	47	47

Note: See Section 4.1.4 for discussion of TSI calculation.

5.2.2.1.7 Phytoplankton Community

Phytoplankton grab samples were collected from Fort Peck Lake at three sites (i.e., FTPLK1772A, FTPLK1805DW, and FTPLKBDCA02) during the spring and summer of the 5-year period 2005 through 2009 (Plate 22, Plate 23, and Plate 24). The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The general prevalence of these taxonomic divisions in the reservoir, based on taxa occurrence, were Bacillariophyta > Chlorophyta/ Cyanobacteria > Cryptophyta/Pyrrophyta/Chrysophyta > Euglenophyta. The diatoms were generally the most abundant algae throughout the entire sampling period based on percent composition. The Shannon-Weaver genera diversity indices calculated for the phytoplankton samples collected at the three sites ranged from 0.40 to 2.32 and averaged 1.48 at site FTPLK1772A, 1.65 at site FTPLK1805DW, and 1.39 at site FTPLKBDCA02. Dominant phytoplankton genera sampled at the three sites in 2009 (i.e., genera comprising more than 10% of the total biovolume of at least one 2009 sample) included the Bacillariophyta *Asterionella*, *Aulacoseria, Fragilaria, and Stephanodiscus*; Chlorophyta *Pyramimonas*; Chrysophyta *Dinobryon*, Cryptophyta *Rhodomonas*; Cyanobacteria *Anabaena*, *Anabaenopsis*, *and Aphanizomenon*; and Pyrrophyta *Ceratium*. In July or August of every year, Cyanobacteria were the dominant algae in Fort Peck Lake (Plate 22, Plate 23, and Plate 24); however, no concentrations of microcystin above 1 ug/l were monitored in the lake during the 2005 through 2009 period (Plate 1, Plate 3, Plate 4, and Plate 6).

5.2.2.1.8 Impairment of Designated Water Quality Beneficial Uses

Based on the State of Montana's impairment assessment methodology (Section 4.1.6.14.1.6.1), the water quality conditions monitored in Fort Peck Lake during the 5-year period 2005 through 2009 did not indicate any impairment of designated water quality beneficial uses. It is noted that the State of Montana has identified Fort Peck Lake as impaired (drinking water supply) due to lead and mercury (Table 1-3).

5.2.2.2 Water Quality Trends (1980 through 2009)

Water quality trends over the 30-year period of 1980 to 2009 were determined for Fort Peck Lake for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through September at the near-dam, ambient monitoring site (i.e., site FTPLK1772A). Plate 25 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., α = 0.05). For the assessment period, Fort Peck Lake exhibited significant trends for Secchi depth (decreasing), chlorophyll *a* (increasing), and TSI (increasing) (Plate 25). No significant trend was detected for total phosphorus (Plate 25). Over the 30-year period, the reservoir has generally remained in a mesotrophic state (Plate 25).

5.2.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI RIVER INFLOW TO FORT PECK LAKE

5.2.3.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions that were monitored in the Missouri River near Landusky, MT (i.e., site FTPNFMORR1) May through September during the 5-year period 2005 through 2009 are summarized in Plate 26 and Plate 27. A review of these results indicated no major water quality concerns. It is noted that the human health standard for arsenic was exceeded for all three of the samples

collected. The human health standard for arsenic is derived from the maximum contaminant level from Montana's drinking water regulations and uses a bioconcentration factor of 44. Very high levels of total iron and manganese were monitored. Eight of the ten total iron samples exceeded the chronic criterion for aquatic life protection (Plate 27). All of the total iron and 40 percent of the total manganese samples exceeded the secondary maximum contaminant level for aesthetics (Plate 27). The high levels of iron and manganese are believed to be a natural condition associated with the geology and soils of the region.

5.2.3.2 Missouri River Inflow Nutrient Flux Conditions

Nutrient flux rates for the Missouri River inflow to Fort Peck Lake over the 5-year period 2005 through 2009 were calculated based on near-surface water quality samples collected near Landusky, MT (i.e. site FTPNFMORR1) and the instantaneous flow conditions at the time of sample collection (Table 5-4). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) are likely higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the flux rates given for total phosphorus and total organic carbon in Table 5-4 should be considered minimum estimates with the actual flux rates being higher. The maximum flux rates for all the constituents are believed to be attributed to higher nonpoint-source loadings during runoff conditions.

Table 5-4. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Landusky, MT (i.e., site FTPNFMORR1) during May through September over the 5-year period 2005 through 2009.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)[1]	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)[1]
No. of Obs.	23	23	23	23	23	22	22
Mean	8,439	0.0137	0.2673	0.0103	0.1101	0.0050	0.6686
Median	7,830	0.0046	0.1485	n.d.	0.0168	n.d.	0.5486
Minimum	3,978	n.d.	0.0348	n.d.	0.0034	n.d.	0.1675
Maximum	17,500	0.1032	1.3243	0.0467	1.0549	0.0454	1.4370

Note: Nondetectable values set to 0 for flux calculations.
(1) Flux calculations for total phosphorus and total organic carbon are biased estimates based on sampled near-surface concentrations and should be considered minimum estimates of total flux (see text for further discussion).

5.2.3.3 Continuous Water Temperature Monitoring of the Missouri River at USGS Gage Site 06115200 near Landusky, Montana

Through an agreement with the U.S. Geological Survey (USGS), a water temperature monitoring probe was added to the USGS's gage (06115200) on the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1). Beginning in October 2004, hourly water temperature measurements were recorded at the site. Plate 28, Plate 29, Plate 30, Plate 31, and Plate 32 respectively, plot mean daily water temperature and river discharge for the years 2005, 2006, 2007, 2008, and 2009. No water temperature data were collected in 2007 (the temperature monitoring probe became inoperable, and USGS was unable to repair it during 2007).

5.2.4 WATER QUALITY AT THE FORT PECK POWERPLANT

5.2.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 33 and Plate 34 summarize the water quality conditions that were monitored from water discharged through Fort Peck Dam during the 5-year period of 2005 through 2009. A review of these results indicated only one possible water quality concern regarding dissolved oxygen. The 1-day dissolved oxygen minimum criterion of 8.0 mg/l for the protection of coldwater B-2 early life stages was not met for 14 percent of the dissolved oxygen measurements. The 8.0 mg/l criterion is a water column concentration recommended to achieve an in-gravel dissolved oxygen concentrations of 5.0 mg/l. For species that have early life stages exposed directly to the water column, the criterion is 5.0 mg/l. No dissolved oxygen measurements were below 5.0 mg/l. The B-2 classification of the Missouri River downstream of Fort Peck Dam only extends to the confluence of the Milk River, a distance of approximately 10 miles. Given the coldwater species and recruitment present, the 5.0 mg/l water column dissolved criterion may be appropriate for this reach. Also, the dissolved oxygen measurements below 8.0 mg/l tended to occur in later summer when the effects on early life stages are likely to be reduced. Therefore, the observed dissolved oxygen measurements below 8.0 mg/l are not believed to be a significant water quality concern at this time.

5.2.4.2 Impairment of Designated Water Quality Beneficial Uses

Based on the State of Montana's impairment assessment methodology (Section 4.1.6.1), the water quality conditions monitored at the Fort Peck powerplant during the 5-year period 2005 through 2009 did not indicate any impairment of designated water quality beneficial uses. It is noted that the State of Montana has identified the Missouri River downstream of Fort Peck Dam as impaired (cold and warm water fisheries) due to water temperature (Table 1-3).

5.2.4.3 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time-series plots for temperature, dissolved oxygen, and dam discharge monitored at the Fort Peck powerplant during the 5-year period of 2005 through 2009 were constructed. Water temperatures showed seasonal warming and cooling through each calendar year (Plate 35 - Plate 44). Dissolved oxygen levels remained relatively high and stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall (Plate 45 - Plate 54). The lowest dissolved oxygen levels occurred during the late summer/early fall period. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. The decreasing dissolved oxygen in the July to September period is attributed to ongoing degradation of dissolved oxygen in the lower hypolimnion of Fort Peck Lake as the summer progressed. Water is withdrawn from the reservoir into the dam's power tunnels approximately 65 feet above the reservoir bottom. There appeared to be little correlation between discharge rates and measured water temperature and dissolved oxygen concentrations (Plate 35 - Plate 54).

5.2.4.4 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Fort Peck Lake

Plate 55, Plate 56, Plate 57, and Plate 58, respectively, plot the mean daily water temperatures monitored at the Missouri River near Landusky, MT (site FTPNFMORR1) and the Fort Peck Dam powerplant (site FTPPP1) for 2005, 2006, 2008, and 2009. Inflow temperatures of the Missouri River to Fort Peck Lake are generally warmer than the outflow temperatures of Fort Peck Dam during the period of March through August. Outflow temperatures of the Fort Peck Dam discharge are generally warmer than the inflow temperatures of the Missouri River during the period of September through February. A

maximum temperature difference occurs in the summer when the Missouri River inflow temperature is about 10°C warmer than the Fort Peck Dam outflow temperature. A plot for 2007 comparing water temperatures of the Missouri River inflow and outflow to Fort Peck Lake was not possible because water temperatures were not recorded at the USGS gage near Landusky, MT (06115200) in 2007 due to equipment problems.

5.2.4.5 <u>Nutrient Flux Conditions of the Fort Peck Dam Discharge to the Missouri River</u>

Nutrient flux rates for the Fort Peck Dam discharge to the Missouri River over the 5-year period 2005 through 2009 were calculated based on samples taken from the Fort Peck powerplant (i.e. site FTPPP1) and the dam discharge at the time of sample collection (Table 5-5). The samples collected in the powerplant are taken from the raw water supply line and are believed to be unbiased regarding particulate-associated constituents. Therefore, the flux rates calculated for the Fort Peck Dam discharge give an unbiased estimate of the flux rates for all the constituents, including total phosphorus and total organic carbon. The maximum flux rates for all the constituents are believed to be attributed to higher dam discharges.

Table 5-5. Summary of nutrient flux rates (kg/sec) calculated for the Fort Peck Dam discharge to the Missouri River (i.e., site FTPPP1) during January through December over the 5-year period 2005 through 2009.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	51	51	51	51	51	43	50
Mean	6,272	0.0068	0.0779	0.0022	0.0055	0.0016	0.4751
Median	5,905	0.0032	0.0455	n.d.	0.0035	n.d.	0.4294
Minimum	3,000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	12,513	0.0739	0.0862	0.0033	0.0249	0.0082	1.5155

Note: Nondetectable values set to 0 for flux calculations.

5.2.5 WATER QUALITY IN THE MISSOURI RIVER DOWNSTREAM FROM FORT PECK DAM

Water temperatures have been monitored in the Missouri River downstream of Fort Peck Dam over the past several years as part of a multi-agency effort to study the pallid sturgeon population in the Missouri and Yellowstone Rivers. Three sites on the Missouri River that have been monitored by the USGS under this effort are the Fort Peck Dam tailwaters (RM1765), Nickels Rapids (RM1757.5), and Frazer Rapids (RM1748).

The water temperatures monitored at the Fort Peck Dam powerplant during the period 2005 through 2009 were plotted with the Missouri River water temperatures monitored by the USGS. Plate 59, Plate 60, Plate 61, Plate 62, and Plate 63, respectively, plot mean daily water temperatures monitored at the sites and the mean daily discharge of Fort Peck Dam from May through October during 2005, 2006, 2007, 2008, and 2009. During the 5 years, water temperatures monitored at the Fort Peck Dam powerplant from June through August were generally 1°C to 2°C cooler than the water temperatures monitored in the Missouri River at the Fort Peck Dam tailwaters site, and 3°C to 4°C cooler than the water temperatures monitored in the Missouri River at Frazer Rapids. During early to mid-September of each year, water temperatures monitored at the three sites were somewhat similar. In early September the water temperatures monitored at the Fort Peck Dam powerplant exhibited warming. This is attributed to

the cooling and downward expansion of the epilimnion in Fort Peck Lake as “fall turnover” of the reservoir approached. It appears that in early September the downward expanding epilimnion intersected with the upper reaches of “withdrawal zone” of the intake for the power tunnels. This resulted in warmer epilimnetic warmer being captured in the reservoir and discharged through Fort Peck Dam. During late-September to early October, water temperatures monitored at the Fort Peck powerplant were generally warmer than those monitored in the Missouri River downstream of Fort Peck Dam. This is attributed to the slower heat loss from Fort Peck Lake than the Missouri River in early fall. Warmer water from the epilimnion of Fort Peck Lake is discharged through Fort Peck Dam that cools as it moves down the Missouri River. It is during this time period that the relationship of warmer water temperatures occurring in the Missouri River at Frazer Rapids and cooler water temperatures occurring at the Fort Peck Dam powerplant reverses.

5.3 GARRISON

5.3.1 BACKGROUND INFORMATION

5.3.1.1 Project Overview

Garrison Dam is located in central North Dakota on the Missouri River at RM 1389.9, about 75 miles northwest of Bismarck, ND and 11 miles south of the town of Garrison, ND. Construction of the project began in 1946, and closure of Garrison Dam in 1953 resulted in the formation of Garrison Reservoir (Lake Sakakawea), which is the largest Corps reservoir in the United States. When full, the reservoir is 178 miles long, up to 6 miles wide, and has 1,884 miles of shoreline. The reservoir contains almost a third of the total storage capacity of the Mainstem System, nearly 24 million acre-ft (MAF). Table 5-6 summarizes how the surface area, volume, mean depth, and retention time of Lake Sakakawea vary with pool elevations. The reservoir has recovered from recent drought conditions and was at pool elevation of 1840.0 ft-msl at the end of December 2009. This is 15.3 feet higher than the reservoir was 1-year ago at the end of 2008. At a pool elevation of 1840.0 ft-msl, Lake Sakakawea is 2.5 feet above the top of the Carryover Multiple Use Zone (1837.5 ft-msl). Major inflows to the reservoir are the Missouri and Yellowstone Rivers, and a minor inflow is the Little Missouri River. Water discharged through Garrison Dam for power production is withdrawn from Lake Sakakawea at elevation 1672.0 ft-msl, approximately 2 feet above the reservoir bottom. **Error! Reference source not found.** shows a schematic drawing of the outlet works at Garrison Dam.

Garrison was authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Over the period 1967 through 2009, the five generating units at Garrison Dam have produced an annual average 2.250 MWh of electricity, which has a current revenue value of approximately $37 million. The recent drought in the western United States has curtailed releases and power production at the Mainstem System projects, including Garrison. Power production at the Garrison Dam generating units averaged an annual 1.396 MWh over the 5-year period 2005 through 2009. Habitat for two endangered species, pallid sturgeon and interior least tern, and one threatened species, piping plover, occurs within the project area. The reservoir is used as a water supply by some individual cabins and by the towns of Williston (RM1553), Four Bears (RM1481), Mandaree (RM1467), Twin Buttes (RM1432), White Shield (RM1415), Parshall (RM1451), Garrison (RM1395), Riverdale (RM1390 – Garrison Dam), and Pick City (RM1390 – Garrison Dam), ND. The Shared Southwest Pipeline Project intake is at RM1414 (Dickinson, ND). Lake Sakakawea is an important recreational resource and a major visitor destination in North Dakota.

Figure 5-4. Schematic drawing of outlet works at Garrison Dam.

Table 5-6. Surface area, volume, mean depth, and retention time of Lake Sakakawea at different pool elevations based on 1988 survey.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1855	384,480	24,203,180	63.0	1.58
1850	364,265	22,331,620	61.3	1.46
1845	344,460	20,558,360	59.7	1.34
1840	320,600	18,893,560	58.9	1.23
1835	296,210	17,355,220	58.6	1.13
1830	280,520	15,916,490	56.7	1.04
1825	263,525	14,556,980	55.2	0.95
1820	249,665	13,275,410	53.2	0.87
1815	235,600	12,061,430	51.2	0.79
1810	219,955	10,921,980	49.7	0.71
1805	204,453	9,861,138	48.2	0.64
1800	188,998	8,877,219	47.0	0.58
1795	173,070	7,973,682	46.1	0.52
1790	161,295	7,139,184	44.3	0.47
1785	148,759	6,364,791	42.8	0.42
1780	138,809	5,646,736	40.7	0.37
1775	128,261	4,979,890	38.8	0.33

Average Annual Inflow (1967 through 2009) = 16.23 Million Acre-Feet
Average Annual Outflow: (1967 through 2009) = 15.30 Million Acre-Feet
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1854-1850 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 1850-1837.5 ft-msl), Carryover Multiple Use Zone (elev. 1837.5-1775 ft-msl), and Permanent Pool Zone (elev. 1775-1670 ft-msl). All elevations are in the NGVD 29 datum.

5.3.1.2 Water Quality Standards Classifications and Section 303(d) Listings

5.3.1.2.1 Lake Sakakawea

The State of North Dakota has classified Lake Sakakawea as a Class 1 lake. As such, the reservoir is to be protected for a coldwater fishery; swimming, boating, and other water recreation; irrigation; stock watering; wildlife; and municipal or domestic use after appropriate treatment. Pursuant to Section 303(d) of the Federal Clean Water Act, North Dakota has placed the Lake Sakakawea on the State's list of impaired waters citing impairment to the uses of fish and other aquatic biota and fish consumption. The impairment of fish and other aquatic biota is attributed to the stressors of low dissolved oxygen and warm water temperatures, and the impairment to fish consumption is attributed to methyl-mercury contamination of fish tissue. The State of North Dakota has issued a fish consumption advisory for Lake Sakakawea due to mercury concerns.

5.3.1.2.2 Missouri River Downstream of Garrison Dam

The State of North Dakota has classified the entire Missouri River as a Class 1 stream. As such, the river is to be suitable for the propagation and/or protection of resident fish species and other aquatic biota; swimming, boating, and other water recreation; irrigation; stock watering; wildlife; and municipal or domestic use after appropriate treatment. The river has not been placed on the State's Section 303(d) list of impaired waters. The State of North Dakota has issued a fish consumption advisory for the Missouri River due to mercury concerns.

5.3.1.3 <u>Management of Coldwater Habitat in Lake Sakakawea</u>

5.3.1.3.1 Coldwater Habitat Criteria – Water Temperature and Dissolved Oxygen

North Dakota defines Class 1 lakes, including Lake Sakakawea, as waters capable of supporting growth of coldwater fish species (e.g., salmonids) and associated biota. Water temperature and dissolved oxygen levels are primary water quality factors that determine the suitability of water for coldwater aquatic life. The State of North Dakota has promulgated a hypolimnetic maximum temperature criterion of 15°C for Class 1 lakes and reservoirs that are thermally stratified. The State also adopted a water quality standard that states that Lake Sakakawea must maintain a minimum volume of water of 500,000 acre-feet that has a temperature of 15°C or less and a dissolved oxygen concentration of not less than 5 mg/l.

5.3.1.3.2 Implementation of Short-term Water Quality Management Measures to Preserve Coldwater Habitat in Lake Sakakawea

The most crucial period for the support of coldwater habitat in Lake Sakakawea is when it begins to cool in late summer. As the thermocline moves deeper, the volume of the coldwater hypolimnion continues to decrease while the expanding epilimnion has not cooled enough to be supportive of coldwater habitat. At the same time, hypolimnetic dissolved oxygen concentrations are approaching their maximum degradation and low dissolved oxygen levels are moving upward from the reservoir bottom and "pinching off" coldwater habitat from below. This situation continues to worsen until the epilimnion cools enough to be supportive of coldwater habitat and the reservoir eventually experiences fall turnover. The volume of the hypolimnion (i.e., coldwater habitat) occurring in Lake Sakakawea during the summer decreases with lower pool levels.

As drought conditions persisted in early 2005, water levels in Lake Sakakawea had fallen to a record low pool elevation of 1805.8 feet-msl on May 12, 2005. At that time it was felt that unless emergency water quality management measures were implemented in 2005 to preserve the coldwater habitat in the reservoir, the recreational sport fishery would likely be adversely impacted. The reduction of coldwater habitat is exacerbated by withdrawals through the Garrison Dam intake structure. Because the invert elevation of the intake portals to the Garrison Dam power tunnels (i.e., penstocks) is 2 feet above the reservoir bottom, water drawn through the penstocks comes largely from the lower depths of the reservoir. Thus, during the summer thermal-stratification period, water is largely drawn from the hypolimnetic volume of Lake Sakakawea. Three short-term water quality management measures were identified for implementation in 2005 in an effort to preserve the coldwater habitat in the reservoir. These measures, which were implemented at Garrison Dam, included: 1) application of a plywood barrier to the dam's intake trash racks, 2) utilization of head gates to restrict the opening to the dam's power tunnels, and 3) modification of the daily flow cycle and minimum flow releases from the dam. The three implemented water quality management measures were targeted at drawing water into the dam from higher elevations within Lake Sakakawea.

5.3.1.3.2.1 Application of a Plywood Barrier to the Dam's Intake Trash Racks

The five power tunnels at Garrison Dam are screened at the upstream end of the water passage by trash racks. These trash racks prevent large objects from entering the penstocks and causing serious damage to the wicket gates and turbine. Each of the five Units has two intake passages for a total of ten intakes. The trash rack for each of the ten intakes consists of seven separate frame sections. The trash rack fits into the trash rack slots at the front of the intake passage piers. A hook for each rack is fixed to the top of the frame. A lifting beam and mobile crane is used to raise and lower each trash rack.

The existing trash racks were modified to raise the elevation where water was withdrawn from Lake Sakakawea. The trash rack modification consisted of installing plywood sheathing on the upstream side of the existing trash rack grates on the passages to Units 1, 2 and 3. The plywood sheathing was applied to Units 2 and 3 in July 2005 and covered the lower 48 feet of the trash racks (i.e., approximately elevation 1672 to 1720 ft-msl) with the exception of a 3-inch slot at the very bottom for passing sediments. In mid-May 2007, attempts were made to install plywood barriers to the trash racks of Unit 1. Due to a large tree at the bottom of the east intake to Unit 1, plywood could not be installed on all the trash racks. The bottom trash rack on the east side of Unit 1 could not be removed and did not receive a plywood barrier. There are 2½ trash racks with plywood barriers on the east side of Unit 1 and 3½ trash racks with plywood on the west side. Therefore, a plywood barrier existed on the west side of Unit 1 from elevation 1672 to 1720 ft-msl, and on the east side of Unit 1 from elevation 1688 to 1720 ft-msl. With the recovery of pool elevations in Lake Sakakawea in 2009, the plywood barriers were removed from the trash racks of all three Units in mid-October 2009.

5.3.1.3.2.2 Utilization of Head Gates to Restrict the Opening to the Dam's Power Tunnels

Each of the intake passages to all five power tunnels have operational head gates that control flow into the penstocks. It was reasoned that lowering one of the two head gates to block a single passage to the power tunnel should increase the velocity of water drawn into the power tunnel, given the total flow through the power tunnel remained the same. Increasing the velocity of the water drawn into the intake could pull water from a higher elevation in Lake Sakakawea and possibly help maintain the reservoir's deeper, coldwater volume. To implement this measure in 2006, single head gates on the passages to Units 1 and 4 were lowered on July 5, 2006. Similarly in 2007, single head gates on the passages to Units 1 and 4 were lowered on May 30, 2007 and were raised on October 2, 2007. The head gates were not lowered in 2008 or 2009.

5.3.1.3.2.3 Modification of Daily Flow Cycle and Maximum and Minimum Flow Releases

Past water quality monitoring at the Garrison Dam powerhouse indicated that the vertical extent of the withdrawal zone in Lake Sakakawea during summer thermal stratification was dependent on the discharge rate of the dam. Warmer water high in dissolved oxygen was drawn down from higher elevations in the reservoir under higher discharge rates, and colder water low in dissolved oxygen was drawn from the lower depths of the reservoir under lower discharge rates. The influence of the dam's discharge rate on the reservoir withdrawal zone is believed to be partly attributed to the design of the intake structure and submerged intake channel.

To the extent possible, flow releases from Garrison Dam during 2005 through 2008 were modified to try to maximize the water drawn from higher elevations and minimize the water drawn from lower elevations in Lake Sakakawea. The following two flow release modifications were pursued: 1) daily flow releases should be in either a maximum or minimum mode; and 2) minimum flows should be discharged through Units 2 and 3, which have the "full" plywood barriers in place. Unit 1, with a "partial" plywood barrier, should be used as a back-up to Units 2 and 3 for discharging minimum flows.

5.3.1.3.3 Performance Assessment Report

A more detailed discussion of the implementation of the short-term water quality management measures and their effects through 2005 is given in the Performance Assessment Report, "Garrison Cold Water Fishery Performance Assessment" (USACE, 2006b).

5.3.1.4 <u>Ambient Water Quality Monitoring</u>

The District has monitored water quality conditions at the Garrison Project since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow to and outflow from the reservoir. A 3-year intensive water quality survey was completed at the Garrison Project in 2005 and the findings of the intensive survey are available in the separate report, "Water Quality Conditions Monitored at the Corps' Garrison Project in North Dakota during the 3-Year period 2003 through 2005" (USACE, 2006c). Figure 5-5 shows the location of sites at the Garrison Project that have been monitored by the District for water quality during the 5-year period 2005 through 2009. The near-dam location (i.e., site GARLK1390A) has been continuously monitored since 1980.

5.3.2 WATER QUALITY IN LAKE SAKAKAWEA

5.3.2.1 <u>Existing Water Quality Conditions</u>

5.3.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Lake Sakakawea at sites GARLK1390A, GARLK1412DW, GARLK1445DW, and GARLK1481DW from May through September during the 5-year period 2005 through 2009 are summarized in Plate 64, Plate 65, Plate 66, and Plate 67. A review of these results indicated possible water quality concerns regarding water temperature and dissolved oxygen for the support of coldwater fishery habitat in the hypolimnion of Lake Sakakawea. For assessment purposes, the top of the hypolimnion was generally defined as the depth where a temperature drop of at least 0.5°C last occurs over a 1-meter depth increment. Monitored water quality conditions in the hypolimnion of Lake Sakakawea regularly exceeded the 15°C and 5 mg/l criteria for temperature and dissolved oxygen. Dissolved oxygen levels in the hypolimnion continually degrade along the reservoir bottom as summer progresses. Dissolved oxygen levels fall below 5 mg/l in the upstream reaches of the hypolimnion first and progress towards the dam. Also, as the summer progresses, low dissolved oxygen conditions move up from the reservoir bottom into the mid and upper reaches of the hypolimnion. This pinching off of coldwater habitat threatens the support of the coldwater fishery in the reservoir, especially under low pool levels during drought conditions. The assessment of coldwater fishery habitat in Lake Sakakawea is further discussed in Section 5.3.2.1.4. The lowest dissolved oxygen concentration measured in Lake Sakakawea over the 5-year period was 1.0 mg/l and occurred at site GARLK1445DW in August 2006.

5.3.2.1.2 Summer Thermal Stratification

5.3.2.1.2.1 Monthly Longitudinal Temperature Contour Plots

Late-spring and summer thermal stratification of Lake Sakakawea during 2009 is described by longitudinal temperature contour plots along the length of the reservoir (Plate 68, Plate 69, Plate 70, Plate 71, and Plate 72). The contour plots are based on depth-profile temperature measurements taken monthly from May through September along the submerged Missouri River channel. As seen in the contour plots, water temperature in Lake Sakakawea varies longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. The near-surface water in the upstream reaches of the reservoir warms up sooner in the spring than the near-surface water near the dam (Plate 68 and Plate 69). By mid-summer a strong thermocline becomes established in the downstream reaches of the reservoir, and the near-surface waters of the entire reservoir above the thermocline are a fairly uniform temperature (Plate 70 and Plate 71). As the near-surface waters of the reservoir cool in the late summer, the thermocline is pushed deeper and the wind-mixed upper waters are fairly uniform in temperature (Plate 72). The vertical variation in temperature is most prevalent in the deeper area of the reservoir towards the dam where a strong thermocline becomes established during the summer. The shallower upstream reaches of Lake Sakakawea do not exhibit much vertical variation of temperature during mid to late summer as wind action allows for the water column to completely mix.

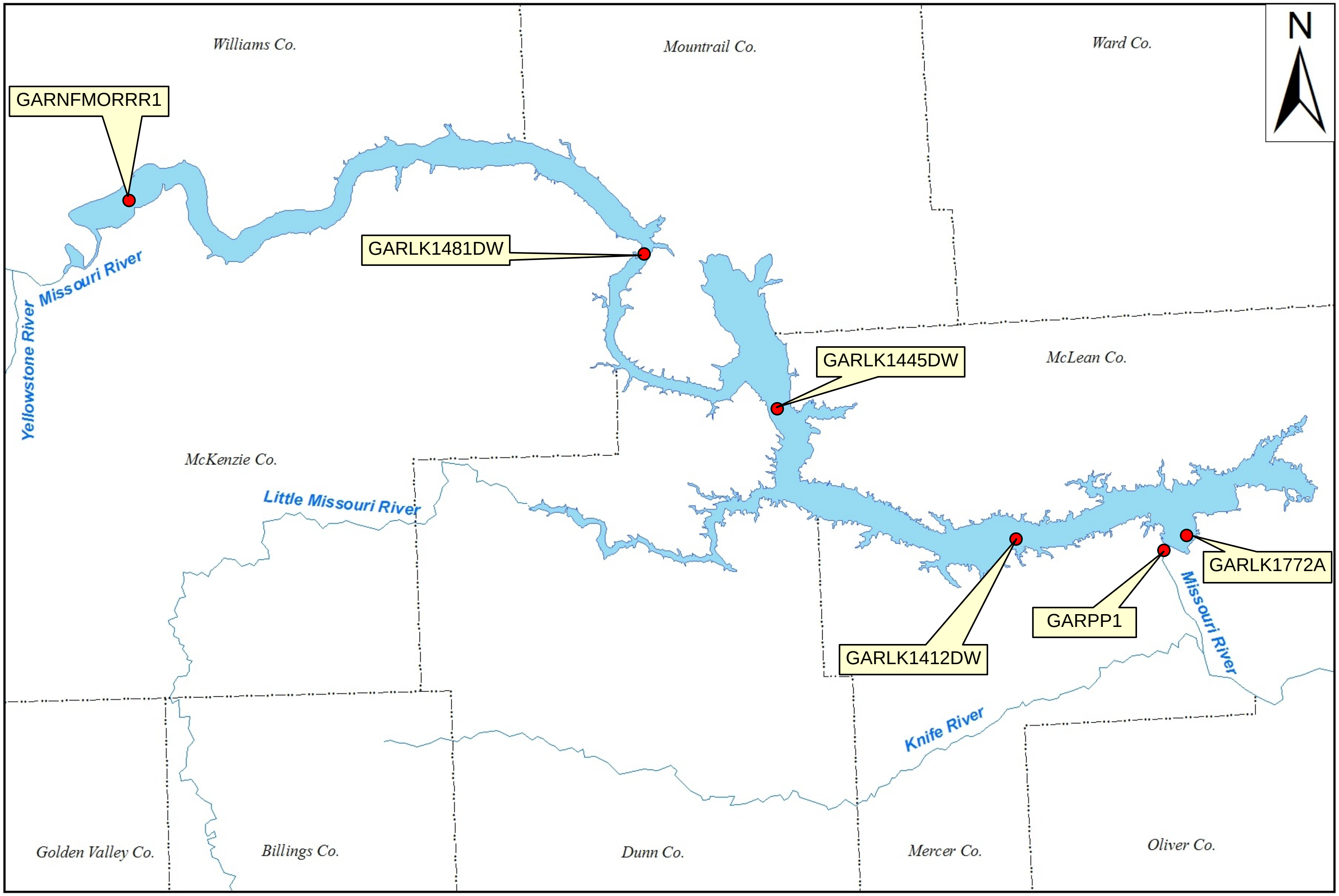

Figure 5-5. Location of sites where water quality monitoring was conducted by the District at the Garrison Project during the 5-year period 2005 through 2009.

5.3.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Lake Sakakawea at the deep water area near the dam is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summer were compiled (Plate 73). The plotted depth-profile measurements indicate that a significant temperature-depth gradient occurs in Lake Sakakawea in the near-dam lacustrine area during the summer, and a thermocline becomes established at a depth of about 25 meters (Plate 73).

5.3.2.1.3 Summer Dissolved Oxygen Conditions

5.3.2.1.3.1 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen contour plots were constructed along the length of Lake Sakakawea based on depth-profile measurements taken in May, June, July, August, and September of 2009 (Plate 74, Plate 75, Plate 76, Plate 77, and Plate 78). During the summer of 2009, dissolved oxygen conditions in Lake Sakakawea varied longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Dissolved oxygen levels below 5 mg/l first appeared near the reservoir bottom in the middle reaches of the reservoir in July (Plate 76). As the summer progressed, dissolved oxygen concentrations below 5 mg/l expanded in the middle reaches or the reservoir, and lower dissolved oxygen levels moved along the reservoir bottom to the area near the dam (Plate 77 and Plate 78). The earlier occurrence of low dissolved oxygen concentrations in the near-bottom water of the middle reaches of Lake Sakakawea is attributed to the increased allochthonous organic loading in the transition zone of the reservoir and the lesser hypolimnetic volume available for assimilation of the oxygen demand. As this material decomposes, a "pool" of water with low dissolved oxygen levels accumulates near the bottom in this area of the reservoir. Decomposition of autochthonous organic matter also occurs in the lacustrine zone and results in dissolved oxygen degradation as the summer progresses, although at a slower rate than what occurs in the transition zone. The recovery of near-bottom dissolved oxygen concentrations to saturation levels takes longer in the lacustrine zone nearer the dam because of the longer time needed for thermal stratification to breakdown and mixing within the water column to occur in the deeper water. The near-bottom location of the power tunnel intakes at the dam could also seemingly result in an interflow along the reservoir bottom that could promote the movement of oxygen-demanding material and low dissolved oxygen water from the middle reaches of the reservoir to the dam. Any interflow affect would likely increase as pool elevations drop and the reservoir's retention time decreases.

5.3.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Lake Sakakawea at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured over the past 5 years. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 79). Dissolved oxygen levels exhibited a significant gradient with depth and tended toward a clinograde vertical distribution (Plate 79). During the period of 2005 through 2008, dissolved oxygen concentrations in the lower hypolimnion fell below 5 mg/l as the summer progressed, with the lowest levels occurring in late-August and September. However, no dissolved oxygen concentration below 6.0 mg/l was monitored at the near-dam site in 2009. The lowest dissolved oxygen concentration measured at this site over the past 5 years was 3.8 mg/l (Plate 64 and Plate 79).

5.3.2.1.4 Occurrence of Coldwater Fishery Habitat in Lake Sakakawea

The occurrence of coldwater habitat (i.e., water temperature ≤ 15°C and dissolved oxygen ≥ 5 mg/l) in Lake Sakakawea was estimated from collected water temperature and dissolved oxygen depth-

profile measurements and defined reservoir elevation and volume relationships. Plate 80 displays a plot of pool elevations and the coldwater fishery habitat estimated to have been present in Lake Sakakawea during the summers of 2003 through 2009. As previously mentioned, the State of North Dakota recently promulgated a water quality standard that states that Lake Sakakawea must maintain a minimum volume of water of 500,000 acre-feet that has a temperature of 15°C or less and a dissolved oxygen concentration of not less than 5 mg/l. Plate 81 displays the same information shown in Plate 80 except the y-axis is scaled to a maximum value of 4-million acre-feet. This allows the estimated coldwater habitat volumes near the 500,000 acre-feet water quality standard to be better discerned. During the 7-year period 2003 through 2009, the 500,000 ac-ft water quality standard was seemingly not met in Lake Sakakawea in late-summer (i.e., September) in any of the 7 years except 2009. There is seemingly a critical period for the occurrence of coldwater habitat in Lake Sakakawea during and just prior to fall turnover of the reservoir.

The 500,000 ac-ft water quality standard of temperature ≤15°C and dissolved oxygen ≥ 5 mg/l for the hypolimnion of Lake Sakakawea was only met in 2009 (Plate 81). Although Lake Sakakawea had not turned over when monitored on September 22, 2009, it is believed a significant enough volume of coldwater habitat existed to allow the 500,000 ac-ft standard to be met until lake-turnover occurred. *(Note: Continuous temperature monitoring at the Garrison powerplant indicates that the area of Lake Sakakawea near Garrison Dam had completely turned over by October 15 with an isothermal temperature of about 12°C present – see Plate 115 and Plate 130.)* As indicated in Plate 80 and Plate 81, significantly more coldwater habitat was estimated to be present in 2009 versus 2003 through 2008. This is largely attributed to the higher pool elevations that occurred at Lake Sakakawea throughout 2009. However, it is also believed that the cool weather that occurred during the May through August period of 2009 may have had an effect. Based on the heating/cooling degree days recorded for Garrison, North Dakota during the 4-month period May through August for the years 2003 through 2009, the May through August period of 2009 was the coolest of the seven years (Plate 82).

The occurrence of coldwater habitat in Lake Sakakawea is believed to be highly dependent on pool elevation. Since coldwater habitat only occurs in the hypolimnion of the reservoir during the summer, the size of the hypolimnion will directly determine the amount of coldwater habitat potentially available. The upper extent of the hypolimnion is delineated by the thermocline (i.e., zone of rapid temperature decline) which separates the colder hypolimnion from the warmer, less dense water of the epilimnion. Depending on climatic factors, the thermocline in an individual reservoir will generally be established at a similar depth from year to year. Therefore, a greater hypolimnetic volume will tend to occur under higher pool elevations and a lesser hypolimnetic volume will tend to occur under lower pool elevations. The pool elevation in late-spring and early summer when the thermocline first becomes established is especially important as later changes in pool elevations are mitigated somewhat by the stratification already established. A larger hypolimnetic volume also has a greater assimilative capacity for oxygen demanding materials which can degrade dissolved oxygen levels in the hypolimnion below the coldwater habitat standard of 5 mg/l.

The relationship between the occurrence of coldwater habitat and pool elevation is generally seen in the coldwater habitat estimated to have occurred in Lake Sakakawea during 2003 through 2009 (Plate 80 and Plate 81). The years with the highest pool elevations (i.e., 2009 and 2003) generally had the highest estimated occurrence of coldwater habitat. The years with the lower pool elevations (i.e., 2005, 2006, and 2007) generally had the lowest estimated occurrence of coldwater habitat. It is noted that 2004 was an atypical year of cloudy, cooler weather that resulted in cooler lake temperatures. Atypical pool elevations occurred in 2008. In 2008, pool elevations rose from the lowest level to near the highest levels recorded during the 6-year period 2003 through 2008 (Plate 80). The seemingly lower occurrence of coldwater habitat estimated in 2008 may be a result of the lower pool levels that occurred in late-spring when the hypolimnion was becoming established.

5.3.2.1.5 Water Clarity

5.3.2.1.5.1 Secchi Transparency

Figure 5-6 displays a box plot of the Secchi depth transparencies measured along Lake Sakakawea at the four sites GARLK1481DW, GARLK1445DW, GARLK1412DW, and GARLK1390A during the 5-year period 2005 through 2009. Secchi depth transparency significantly increased in a downstream direction between sites GARLK1481DW, GARLK1445DW, and GARLK1412DW (Figure 5-6). This is attributed to suspended sediment in the inflowing Missouri River settling out in the reservoir as current velocities slow. The surface waters near Garrison Dam are significantly clearer than the upstream regions of the reservoir. Under the conditions that were monitored during the 5-year period 2005 to 2009, it appears that site GARLK1481DW was in the riverine zone; site GARLK1445DW was in the transition zone; and sites GARLK1412DW and GARLK1390A were in the lacustrine zone of the reservoir.

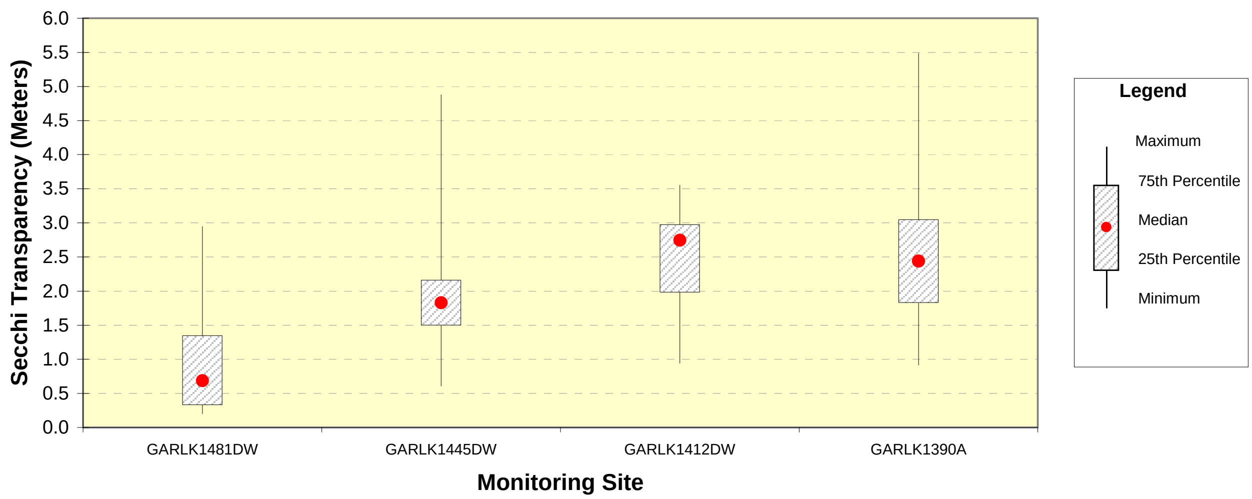

Figure 5-6. Box plot of Secchi transparencies measured in Lake Sakakawea during the 5-year period 2005 through 2009.

5.3.2.1.5.2 Turbidity

Monthly (May through September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 during 2009 (Plate 83, Plate 84, Plate 85, Plate 86, and Plate 87). As seen in the contour plots, turbidity levels in Lake Sakakawea vary longitudinally from the dam to reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Turbidity levels are significantly higher in the upstream reaches of the reservoir as compared to the area near the dam. This is attributed to the turbid conditions of the inflowing Missouri River. It also appears that turbidity plumes may move through Lake Sakakawea as interflows; especially along the bottom. This may be attributed to colder inflowing snowmelt runoff, with higher turbidity levels, flowing underneath warmer surface waters in Lake Sakakawea as an interflow along the bottom. Given the low chlorophyll *a* concentrations monitored in Lake Sakakawea, turbidity in the reservoir appears to be largely due to suspended inorganic material.

5.3.2.1.6 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Lake Sakakawea during the summer were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 1-meter of the reservoir bottom. The compared samples were collected at the near-dam site GARLK1390A during the 5-year period 2005 through 2009. During the period a total of 19 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 88). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for all the assessed parameters except total Kjeldahl nitrogen, total ammonia, and total phosphorus. Parameters that were significantly lower in the near-bottom water of Lake Sakakawea included: water temperature ($p < 0.001$), dissolved oxygen ($p < 0.001$), pH ($p < 0.001$), and TOC ($p < 0.05$). Parameters that were significantly higher in the near-bottom water included: ORP ($p < 0.001$) and alkalinity ($p < 0.05$).

5.3.2.1.7 Reservoir Trophic Status

Trophic State Index (TSI) values for Lake Sakakawea were calculated from monitoring data collected during the 5-year period 2005 through 2009 (Table 5-7). The calculated TSI values indicate that the lacustrine zone of the reservoir (i.e., sites GARLK1390A and GARLK1412DW) is mesotrophic, the transition zone (i.e., site GARLK1445DW) is moderately eutrophic, and the riverine zone (i.e., site GARLK1481DW) is eutrophic. However, it is noted that the calculated average TSI value for the riverine zone is greatly influenced by the low water clarity in this part of the reservoir. This lack of water clarity is largely attributed to suspended inorganic material delivered to the reservoir by the Missouri River. Thus, the higher TSI values in the riverine zone seemingly are not indicative of increased algal growth associated with nutrient enrichment. It is noted that the total phosphorus nutrient guideline defined by North Dakota for lake improvement or management (i.e., 0.02 mg/l) was regularly exceeded throughout Lake Sakakawea (Plate 64, Plate 65, Plate 66, and Plate 67).

Table 5-7. Mean Trophic State Index (TSI) values calculated for Lake Sakakawea. TSI values are based on monitoring at the identified four sites during the 5-year period 2005 through 2009.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
GARLK1390A	47	51	48	49
GARLK1412DW	48	49	50	49
GARLK1445DW	51	49	53	51
GARLK1481DW	65	54	58	59

Note: See Section 4.1.4 for discussion of TSI calculation.

5.3.2.1.8 Phytoplankton Community

Phytoplankton grab samples were collected from Lake Sakakawea at four sites (i.e., GARLK1390A, GARLK1412DW, GARLK1445DW, and GARLK1481DW) during the spring and summer of the 5-year period 2005 through 2009 (Plate 89, Plate 90, Plate 91, and Plate 92). The following eight taxonomic divisions were represented by taxa collected in the phytoplankton samples:

Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The general prevalence of these taxonomic divisions in the reservoir, based on taxa occurrence, were Bacillariophyta > Chlorophyta > Cryptophyta/Cyanobacteria/Pyrrophyta > Chrysophyta > Euglenophyta. The diatoms were generally the most abundant algae throughout the entire sampling period based on percent composition. The Shannon-Weaver genera diversity indices calculated for the phytoplankton samples collected at the four sites ranged from 0.34 to 2.69 and averaged 1.37 at site GARLK1390A, 1.43 at site GARLK1412DW, 1.50 at site GARLK1445DW, and 1.64 at site GARLK1481DW. Dominant phytoplankton genera sampled at the four sites in 2009 (i.e., genera comprising more than 10% of the total biovolume of at least one sample collected in 2009) included the Bacillariophyta *Asterionella, Aulacoseria, Cyclotella, Fragilaria, Stephanodiscus, and Tablellaria*; Chlorophyta *Pyramimonas*; Chrysophyta *Dinobryon*; Cryptophyta *Rhodomonas*; and Cyanobacteria *Cylindrospermopsis and Microcystis*. No concentrations of microcystin above 1 ug/l were monitored in Lake Sakakawea during 2005 through 2009 (Plate 64, Plate 65, Plate 66, and Plate 67).

5.3.2.1.9 Impairment of Designated Water Quality Beneficial Uses

Based on the State's impairment assessment methodology (Section 4.1.6.3), the water quality conditions monitored in Lake Sakakawea during the 5-year period 2005 through 2009 indicate probable impairment of coldwater fishery habitat. The percent of hypolimnetic dissolved oxygen measurements below 5 mg/l ranged from 12 to 65 percent of the measurements taken at the four reservoir monitoring sites (Plate 64, Plate 65, Plate 66, and Plate 67). The estimated "instantaneous" volume of coldwater habitat present in Lake Sakakawea fell below 500,000 ac-ft every year from 2003 through 2008 based on monitored temperature and dissolved oxygen depth-profiles (Plate 80). However, the estimated coldwater habitat seemed to remain above 500,000 ac-ft in 2009 when normal pool levels occurred (Plate 81).

5.3.2.2 <u>Water Quality Trends (1980 through 2009)</u>

Water quality trends over the 30-year period of 1980 through 2009 were determined for Lake Sakakawea for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam, ambient monitoring site (i.e., site GARLK1390A). Plate 93 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Lake Sakakawea did not exhibit significant trends for any of the four parameters (Plate 93). Over the 30-year period, the reservoir has generally remained in a mesotrophic state (Plate 93).

5.3.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI RIVER INFLOW TO LAKE SAKAKAWEA

5.3.3.1 <u>Statistical Summary and Comparison to Applicable Water Quality Standards Criteria</u>

The water quality conditions that were monitored in the Missouri River near Williston, ND (i.e., site GARNFMORRR1) monthly from May through September during the 5-year period 2005 through 2009 are summarized in Plate 94 and Plate 95. A review of these results indicated no major water quality concerns. It is noted that monitored levels of total aluminum greatly exceeded the acute total aluminum criterion for aquatic life protection; however, the monitored levels of dissolved aluminum were well below the criterion. It is not believed the monitored aluminum levels are indicative of a water quality problem. It is also noted that very high levels of total iron were monitored. The high levels of total aluminum and iron are believed to be a natural condition associated with the geology and soils of the region.

5.3.3.2 Missouri River Inflow Nutrient Flux Conditions

Nutrient flux rates for the Missouri River inflow to Lake Sakakawea over the 5-year period 2005 through 2009 were calculated based on near-surface water quality samples collected near Williston, ND (i.e. site GARNFMORRR1) and the instantaneous flow conditions at the time of sample collection (Table 5-8). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) are likely higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the flux rates given for total phosphorus and total organic carbon in Table 5-8 should be considered minimum estimates with the actual flux rates being higher. The maximum flux rates for all the constituents are believed to be attributed to higher nonpoint-source loadings during runoff conditions.

Table 5-8. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Williston, ND (i.e., site GARNFMORRR1) during April through September over the 5-year period 2005 through 2009.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)(1)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)(1)
No. of Obs.	27	27	27	27	27	26	26
Mean	20,254	0.0286	0.8089	0.0630	0.2032	0.0107	1.5881
Median	14,360	0.0117	0.5800	0.0200	0.0866	0.0054	1.1775
Minimum	7,649	n.d.	0.1000	n.d.	0.0152	n.d.	0.4862
Maximum	52,320	0.2193	2.1200	0.2977	0.8612	0.0595	4.5720

Note: Nondetect values set to 0 for flux calculations.
(1) Flux calculations for total phosphorus and total organic carbon are biased estimates based on sampled near-surface concentrations and should be considered minimum estimates of total flux (see text for further discussion).

5.3.3.3 Continuous Water Temperature Monitoring of the Missouri River at USGS Gage Site 06330000 near Williston, North Dakota

Through an agreement with the USGS, a water temperature monitoring probe was added to the USGS's gage (06330000) on the Missouri River near Williston, ND (i.e., site GARNFMORRR1). Beginning in 2005, water temperature measurements were recorded at the site. Plate 96, Plate 97, Plate 98, Plate 99, and Plate 100, respectively, plot mean daily water temperature and river discharge determined for 2005, 2006, 2007, 2008, and 2009.

5.3.4 WATER QUALITY AT THE GARRISON POWERPLANT

5.3.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 101 and Plate 102 summarize the water quality conditions that were monitored from water discharged through Garrison Dam during the 5-year period 2005 through 2009. The monitored water quality conditions do not indicate any significant water quality concerns. All dissolved oxygen concentrations measured during the 2005 through 2009 period were above 5 mg/l. The maximum water temperature measured during the 5-year period was 18.2°C. The monitored water temperatures are believed supportive of the coolwater fishery that exists in the Garrison Dam tailwaters.

5.3.4.2 Impairment of Designated Water Quality Beneficial Uses

Based on the State of North Dakota's impairment assessment methodology (Section 4.1.6.3), the water quality conditions monitored at the Garrison powerplant during the 5-year period 2005 through 2009 did not indicate any impairment of designated water quality beneficial uses.

5.3.4.3 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time series plots for temperature and dam discharge monitored hourly at the Garrison powerplant during the 7-year period of 2003 through 2009 were constructed (Plate 103 - Plate 115). Monitored water temperatures showed seasonal cooling and warming through each calendar year. Daily water temperatures remained fairly stable during the winter, early spring, and late fall and exhibited considerable variability during the late spring, summer, and early fall. When thermal stratification becomes established in Lake Sakakawea during the late spring, the temperature of the water discharged through the dam becomes highly dependent upon the discharge rate of the dam. This indicates that the vertical extent of the withdrawal zone in the reservoir is dependent upon the discharge rate of the dam. This is believed to be a result of the design of the intake structure (i.e., bottom withdrawal) and the presence of the submerged intake channel leading to the intake structure. Water is likely drawn from an extended vertical zone in Lake Sakakawea year-round, but is only evident in the temperatures monitored at the powerplant during thermal stratification of the reservoir in the summer. A decrease in the daily variation of the monitored temperatures in the summers of 2005 through 2009 occurred after the installation of plywood barriers on the lower portion of the trash racks in front of penstocks 2 and 3 in 2005 and penstock 1 in 2007.

Semiannual time series plots for dissolved oxygen and dam discharge monitored hourly at the Garrison powerplant during the 7-year period of 2003 through 2009 were also constructed (Plate 118 - Plate 130). Dissolved oxygen levels remained relatively high and stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall. The lowest dissolved oxygen levels occurred during the late summer/early fall period. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. The decreasing dissolved oxygen in the July to September period is attributed to ongoing degradation of dissolved oxygen in the lower hypolimnion in Lake Sakakawea as the summer progressed. Water is withdrawn from Lake Sakakawea into the dam's power tunnels approximately 2 feet above the reservoir bottom. During the late summer, dissolved oxygen levels were highly correlated to dam discharge rates in 2003, 2004, and 2009; and not as correlated in 2005, 2006, 2007, and 2008. This is attributed to the implementation of the short-term water quality management measures in 2005 through 2009. In early October 2009, the plywood barriers were removed from the lower portions of the trash racks front of Units 1, 2, and 3. This seemingly allowed water with lower dissolved oxygen levels to be pulled from the lower hypolimnion; especially during low discharge periods. This is seen in Plate 130 where dissolved oxygen levels below 5 mg/l were monitored in early October.

5.3.4.4 Discharge of Water through the Five Penstocks at Garrison Dam during the Period Plywood Barriers were in Place

The volume of water that was discharged through each of the five penstocks during the summer over the 5-year period the plywood barriers were in place is shown Table 5-9.

Table 5-9. Volume of water (ac-ft) discharged through the five Units at Garrison Dam during June, July, August, and September over the 5-year period 2005 through 2009.

Month	Volume of Water Discharged (ac-ft)			Percent of Total Water Discharged	
	Units with Barriers	Units with No Barriers	Total	Units with Barriers	Units with No Barriers
2005					
June	230,708	661,713	892,421	0.26	0.74
July	308,887	624,407	933,294	0.33	0.67
August	268,035	685,744	953,779	0.28	0.72
September	436,659	403,104	839,763	0.52	0.48
2006					
June	694,472	486,661	1,181,133	0.59	0.41
July	815,368	449,544	1,264,912	0.64	0.36
August	810,942	504,405	1,315,347	0.62	0.38
September	594,305	483,558	1,077,863	0.55	0.45
2007					
June	761,565	192,863	954,428	0.80	0.20
July	781,339	198,866	980,205	0.80	0.20
August	742,178	241,912	984,090	0.75	0.25
September	453,800	239,363	693,163	0.65	0.35
2008					
June	816,793	36,728	853,521	0.96	0.04
July	824,658	13,338	837,996	0.98	0.02
August	576,549	278,799	855,347	0.67	0.33
September	374,784	359,397	734,181	0.51	0.49
2009					
June	525,668	421,573	947,241	0.55	0.45
July	536,678	428,129	964,807	0.56	0.44
August	554,616	432,190	986,806	0.56	0.44
September	464,676	413,185	877,861	0.53	0.47
October (1-14)	183,711	168,344	352,056	0.52	0.48

5.3.4.5 Comparison of Summer Temperature and Dissolved Oxygen Conditions Monitored at the Garrison Powerplant

Plate 116 and Plate 117 show plots of hourly water temperatures measured at the Garrison powerplant during the period of June through October for 2003 through 2009. During the period 2005 through 2008, it is evident that the installation of the plywood barriers in 2005 reduced the variability and raised the temperature of the water passed through Garrison Dam and discharged to the Missouri River downstream during the summer. The increase in temperature was, on average, about 2°C. However, in 2009 the temperature of the water discharged through Garrison Dam was the coolest of all seven years. This is attributed to three reasons: 1) during 2009 water discharged through Garrison Dam was not maximized through the penstocks with the plywood barriers (Table 5-9); 2) as noted earlier, the summer of 2009 was unusually cool (see Plate 82) and seemingly resulted in cooler lake water temperatures; and 3) 2009 was the only year where "normal" pool elevations occurred all year and resulted in a larger and cooler hypolimnetic volume.

Plate 131 and Plate 132 show a plot of hourly dissolved oxygen concentrations measured at the Garrison powerplant during the period of June through October for 2003 through 2009. It is evident that the installation of the short-term water quality management measures in 2005 raised the dissolved oxygen concentrations of water passed through Garrison Dam and discharged to the Missouri River downstream

during the summer. The plywood barriers allowed epilimnetic water, higher in dissolved oxygen, to be drawn into the power tunnel intakes and then to be discharged from the dam. Although the short-term water quality management measures were implemented to preserve coldwater habitat in Lake Sakakawea, they also had the probable benefit of preventing dissolved oxygen levels below the State of North Dakota's water quality standards criterion (i.e., 5 mg/l) from occurring in the Garrison Dam tailwaters during late summer low flow releases (Plate 132).

5.3.4.6 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Lake Sakakawea

Plate 133, Plate 134, Plate 135, Plate 136, and Plate 137, respectively, plot the mean daily water temperatures monitored at the Missouri River near Williston, ND (site GARNFMORRR1) and the Garrison Dam powerplant (site GARPP1) for 2005, 2006, 2007, 2008, and 2009. Inflow temperatures of the Missouri River to Lake Sakakawea are generally warmer than the outflow temperatures of Garrison Dam during the period of April through September. Outflow temperatures of the Garrison Dam discharge are generally warmer than the inflow temperatures of the Missouri River during the period of October through March. A maximum temperature difference occurs in the summer when the Missouri River inflow temperature is about 10°C warmer than the Garrison Dam outflow temperature.

5.3.4.7 Nutrient Flux Conditions of the Garrison Dam Discharge to the Missouri River

Nutrient flux rates for the Garrison Dam discharge to the Missouri River over the 5-year period 2005 through 2009 were calculated based on samples taken from the Garrison powerplant (i.e. site GARPP1) and the dam discharge at the time of sample collection (Table 5-10). The samples collected in the powerplant are taken from the raw water supply line and are believed to be unbiased regarding particulate-associated constituents. Therefore, the flux rates calculated for the Garrison Dam discharge give an unbiased estimate of the flux rates for all the constituents, including total phosphorus and total organic carbon. The maximum flux rates for all the constituents are believed to be attributed to higher dam discharges.

Table 5-10. Summary of nutrient flux rates (kg/sec) calculated for the Garrison Dam discharge to the Missouri River (i.e., site GARPP1) during January through December over the 5-year period 2005 through 2009.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	51	51	50	51	50	51	49
Mean	16,166	0.0190	0.1951	0.0320	0.0153	0.0059	1.4330
Median	13,729	0.0054	0.1246	0.0268	0.0067	n.d.	1.1496
Minimum	9,402	n.d.	n.d.	n.d.	n.d.	n.d.	0.3461
Maximum	37,300	0.1534	0.7438	0.1056	0.1952	0.0439	3.3911

Note: Nondetectable values set to 0 for flux calculations.

5.3.5 WATER QUALITY IN THE MISSOURI RIVER DOWNSTREAM OF GARRISON DAM

5.3.5.1 Water Temperatures Monitored at Garrison Dam and the USGS Gage Station at Bismarck, North Dakota

Through an agreement with the USGS, a water temperature monitoring probe was added to the USGS's gage on the Missouri River at Bismarck, ND in 2005. The USGS gage at Bismarck, ND is

located at RM1314.7 and is approximately 75 miles downstream of Garrison Dam. Plate 138, Plate 139, Plate 140, Plate 141, and Plate 142, respectively, plot the mean daily flows and water temperatures monitored at the Garrison powerplant and USGS gage at Bismarck, ND in 2005, 2006, 2007, 2008, and 2009. Annually, the mean daily water temperature of the Missouri River at Bismarck is warmer than the Garrison Dam discharge from April through August and generally cooler from September through March. During the summers of 2005, 2006, 2007, 2008, and 2009 mean daily water temperatures at Bismarck were, respectively, up to 11°C, 6°C, 8°C, 7°C, and 10°C warmer than the Garrison Dam discharge. The lower summer temperature differences in 2006, 2007, and 2008 are attributed to the full implementation of the short-term water quality management measures at Garrison Dam and the lower pool elevations in Lake Sakakawea.

5.3.5.2 <u>Water Temperatures Monitored in the Reach from Garrison Dam to Bismarck, ND in 2005, 2006, 2007, and 2009</u>

As part of their fisheries management program, the North Dakota Game and Fish Department (NDGFD) monitored water temperatures in the Missouri River from Garrison Dam (RM1389) to Beaver Bay (RM1259). Sites monitored in 2005 (June through September) included Stanton (RM1372), Burnt Creek (RM1322), Fox Island (RM1312), and Beaver Bay (RM1259). Sites monitored in 2006 (May through September) included Garrison Dam Tailwaters (RM1390), Stanton (RM1372), Washburn (RM1355), Wilton (RM1344), Burnt Creek, and North Beaver (RM1260). Sites monitored in 2007 (May through September) included Garrison Dam Tailwaters (RM1390), Stanton (RM1372), Washburn (RM1355), Wilton (RM1344), and Fox Island (RM1312). Temperature monitors that were deployed by the NDGFD in 2008 failed and no data were recorded. Sites monitored in 2009 (May through mid-October) included Garrison Dam Tailwaters (RM1390), Stanton (RM1372), Washburn (RM1355), Wilton (RM1344), Fox Island (RM1312) and Kimball (RM1300). Plate 143, Plate 144, Plate 145, Plate 146, respectively, plot mean daily water temperatures monitored in the Missouri River downstream from Garrison Dam in 2005, 2006, 2007, and 2009.

5.3.6 MANAGEMENT OF COLDWATER FISHERY HABITAT IN LAKE SAKAKAWEA

5.3.6.1 <u>Implementation of Short-term Water Quality Management Measures to Preserve Coldwater Fishery Habitat in Lake Sakakawea</u>

The potential impact of implementing the short-term water quality management measures on preserving coldwater fishery habitat in Lake Sakakawea during the summers of 2005, 2006, 2007, 2008, and 2009 was estimated by comparing the quantity of water meeting coldwater conditions (i.e., ≤ 15°C and ≥ 5 mg/l dissolved oxygen) that was discharged through each of the dam's five penstocks. The water quality conditions monitored in penstocks 1, 2, and 3 were compared to penstocks 4 and 5. The water quality conditions monitored in penstocks 4 and 5 were taken to be the water quality conditions that would have occurred in penstocks 1, 2, and 3 if the plywood barriers were not in place. Installation of the plywood barriers on Units 2 and 3 was completed on July 22, 2005. The installation of plywood barriers on Unit 1 was completed on May 19, 2007. All of the plywood barriers in front of penstocks 1, 2, and 3 were removed in October 2009. During the summers of 2005, 2006, 2007, and 2008 most of the water discharged through penstocks 4 and 5 prior to September 1 met coldwater habitat conditions, while almost all the water discharged through penstocks 2 and 3 did not (i.e., water was warmer than 15°C). During the summer of 2009, all of the water discharged through penstocks 4 and 5 met coldwater habitat conditions, while some of the water discharged through penstocks 1, 2, and 3 did not (i.e., water was warmer than 15°C). This resulted in a potential saving of coldwater habitat in Lake Sakakawea of about 379,390 acre-ft in 2005, about 1,021,150 acre-ft in 2006, about 827,928 acre-ft in 2007, about 794,850 acre-ft in 2008, and about 87,060 acre-ft in 2009. All of the potential savings of coldwater habitat

occurred prior to early September. In all years except 2009, water temperatures in all the penstocks by early September were above 15°C due to the downward expansion of the epilimnion in Lake Sakakawea. During the summer of 2009 very little water above 15°C was discharged from any penstock, even though the plywood barriers were still in place on penstocks 1, 2, and 3. This resulted in only a small amount of coldwater habitat being potentially saved in 2009. This is attributed to the return of normal pool levels in Lake Sakakawea during all of 2009.

5.4 OAHE

5.4.1 BACKGROUND INFORMATION

5.4.1.1 Project Overview

Oahe Dam is located on the Missouri River at RM 1072.3 in central South Dakota, 6 miles northwest of Pierre, SD. The closing of Oahe Dam in 1958 resulted in the formation of Oahe Reservoir (Lake Oahe). When full, the reservoir is 231 miles long, covers 374,000 acres, and has 2,250 miles of shoreline. Table 5-11 summarizes how the surface area, volume, mean depth, and retention time of Lake Oahe vary with pool elevations. The reservoir has recovered from recent drought conditions of the past decade and was at a pool elevation of 1607.4 at the end of December 2009. This is only 0.1 feet below the top of the Carryover Multiple Use Zone (1607.5 ft-msl). Major inflows to the reservoir are the Missouri and Cheyenne Rivers. Water discharged through Oahe Dam for power production is withdrawn from Lake Oahe at elevation 1524 ft-msl, approximately 114 feet above the reservoir bottom. Figure 5-7 shows a schematic drawing of the outlet works at Oahe Dam.

Table 5-11. Surface area, volume, mean depth, and retention time of Lake Oahe at different pool elevations based on 1989 survey.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1620	374,135	23,136,960	61.8	1.36
1615	350,960	21,323,520	60.8	1.25
1610	325,765	19,630,460	60.3	1.15
1605	300,030	18,068,750	60.2	1.06
1600	281,010	16,618,390	59.1	0.98
1595	260,715	15,265,460	58.6	0.90
1590	245,190	14,002,600	57.1	0.82
1585	229,085	12,816,650	55.9	0.75
1580	213,150	11,711,030	54.9	0.69
1575	196,915	10,686,750	54.3	0.63
1570	182,933	9,737,896	53.2	0.57
1565	168,523	8,859,708	52.6	0.52
1560	155,510	8,049,792	51.8	0.47
1555	141,688	7,308,917	51.6	0.43
1550	133,628	6,622,830	49.6	0.39
1545	124,869	5,976,361	47.9	0.35
1540	116,560	5,373,030	46.1	0.32

Average Annual Inflow (1967 through 2009) = 17.94 Million Acre-Feet
Average Annual Outflow: (1967 through 2009) = 17.03 Million Acre-Feet
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1620-1617 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 1617-1607.5 ft-msl), Carryover Multiple Use Zone (elev. 1607.5-1540 ft-msl), and Permanent Pool Zone (elev. 1540-1415 ft-msl). All elevations are in the NGVD 29 datum.

Figure 5-7. Schematic drawing and photo of power intake structure at Oahe Dam.

Lake Oahe and Dam are authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Over the period 1967 through 2009, the seven generating units at Oahe Dam have produced an annual average 2.621 million mega-watt hours (MWh) of electricity, which has a current revenue value of approximately $40 million. The lingering drought in the interior western United States has curtailed releases and power production at the Missouri River mainstem system projects, including Oahe. Power production at the Oahe Dam generating units averaged an annual 1.396 MWh over the 5-year period 2005 through 2009. Habitat for one endangered species, interior least tern, and one threatened species, piping plover, occurs within the project area. Lake Oahe is used as a water supply by the towns of Fort Yates, ND (RM1244); Wakpala, SD (RM1198); Mobridge, SD (RM1193), and Huron, SD (RM1074), SD. The intake for the WEB Water System is at RM 1184 (serves 45 towns and over 7,000 rural households), and the intake for the Cheyenne River Tribe Mni Water Company is at RM 1110 (Eagle Butte, LaPlante, Swiftbird, Whitehorse, Promise, Dupree, Iron Lightning, Thunder Butte, Faith, Howes, Isabel, Takina, Cherry Creek, Bridger, Lantry, Ridgeview, Red Elm, Red Scaffold, Blackfoot, and Parade, SD). The reservoir is also used as a water supply for individual cabins. Lake Oahe is an important recreational resource and a major visitor destination in South Dakota.

5.4.1.2 Water Quality Standards Classifications and Section 303(d) Listings

5.4.1.2.1 Lake Oahe

Under normal pool levels, Lake Oahe runs along the Missouri River from approximately RM1072 to RM1290, and crosses the North Dakota/South Dakota border which is at RM1232. Therefore under normal pools about 25 and 75 percent of the length of the reservoir is respectively in North Dakota and South Dakota. Water quality standards from each State respectively apply to the portion of the reservoir in each state.

The State of North Dakota has classified Lake Oahe as a Class 1 lake. As such, the reservoir is to be protected for a coldwater fishery; swimming, boating, and other water recreation; irrigation; stock watering; wildlife; and municipal or domestic use after appropriate treatment. Pursuant to Section 303(d) of the Federal CWA, North Dakota has not placed the Lake Oahe on the State's list of impaired waters. The State of North Dakota has issued a fish consumption advisory for Lake Oahe due to mercury concerns.

South Dakota has classified the Missouri River impoundments within the State as flowing streams and not reservoirs (South Dakota Administrative Rules 74:51:01:43). The following water quality-dependent beneficial uses have been designated for Lake Oahe in South Dakota's water quality standards: domestic water supply waters, coldwater permanent fish life propagation waters, immersion recreation waters, limited-contact recreation waters, commerce and industry waters, agricultural water supply (i.e., irrigation and stock watering), and fish and wildlife propagation. The State of South Dakota has not placed the reservoir on the State's Section 303(d) list of impaired waters and has not issued a fish consumption advisory for the reservoir. However, the Cheyenne River Sioux Tribe has issued a fish consumption advisory for Lake Oahe and the Cheyenne and Moreau Rivers. Tribal lands of the Cheyenne River Sioux are located along the east side of Lake Oahe between the Moreau and Cheyenne Rivers.

5.4.1.2.2 Missouri River Downstream of Oahe Dam

The following beneficial uses have been designated by South Dakota in their water quality standards for the Missouri River from Oahe Dam to Lake Sharpe: recreation (i.e., immersion and limited-contact), coldwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e.,

irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of South Dakota has not placed the river on its Section 303(d) list of impaired waters and has not issued a fish consumption advisory for the river.

5.4.1.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at the Oahe Project since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow to and outflow from the reservoir. A 3-year intensive water quality survey was completed at the Oahe Project in 2007, and the findings of the intensive survey are available in the separate report, "Water Quality Conditions Monitored at the Corps' Oahe Project in South Dakota during the 3-year period 2005 through 2007" (USACE, 2008). Figure 5-8 shows the location of sites at the Oahe Project that have been monitored by the District for water quality during the past 5 years (i.e., 2005 through 2009). Water quality monitoring upstream of Mobridge, South Dakota (i.e., RM1196) was not conducted prior to 2009. Drought conditions and low pool levels during this period resulted in the reservoir's upstream boundary receding to near the North Dakota/South Dakota border. The District added a monitoring site on Lake Oahe near Beaver Creek (RM1256) in 2009. The new monitoring site is west of the town of Linton, ND. The near-dam location (i.e., site OAHLK1073A) has been continuously monitored since 1980.

5.4.2 WATER QUALITY IN LAKE OAHE

5.4.2.1 Existing Water Quality Conditions

5.4.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Lake Oahe at sites OAHLK1073A, OAHLK1090DW, OAHLK1110DW, OAHLK1135DW, OAHLK1153DW, OAHLK1176DW OAHLK1196DW, and OAHLK1256DW from May through September during the 5-year period 2005 through 2009 are summarized in Plate 147, Plate 148, Plate 149, Plate 150, Plate 151, Plate 152, Plate 153, and Plate 154. A review of these results indicated possible water quality concerns regarding water temperature and dissolved oxygen for the support of Coldwater Permanent Fish Life Propagation. Water temperatures in the epilimnion of the reservoir regularly exceed 18.3°C in the summer, while temperatures in the hypolimnion are less than 18.3°C. Dissolved oxygen levels in the hypolimnion continually degrade along the reservoir bottom as summer progresses and fall below 7.0 mg/l in late summer (i.e., occurred in non-spawning area outside the spawning season for coldwater species). During the 5-year period, dissolved oxygen levels remained above 6.0 mg/l in the hypolimnion in the area of the reservoir near Oahe Dam (Plate 147 and Plate 148). Dissolved oxygen concentrations regularly fell below 6 mg/l in the middle and upstream reaches of the hypolimnion (Plate 149, Plate 150, Plate 151, Plate 152, Plate 153, and Plate 154). As the summer progressed, conditions of lower dissolved oxygen moved up from the reservoir bottom into the hypolimnion. During the 5-year period 2005 through 2009, a hypolimnion only formed in the upstream reaches of the reservoir (at and upstream Mobridge, South Dakota) with the higher pool elevations in 2009 (Plate 153 and Plate 154). Conditions supportive of Coldwater Permanent Fish Life Propagation (i.e., water temperature ≤18.3°C and dissolved oxygen ≥ 6 mg/l) were present in 100, 100, 86, 55, 55, 25, 27, and 25 percent of the depth-profile measurements respectively taken at sites OAHLK1073A, OAHLK1090DW, OAHLK1110DW, OAHLK1135DW, OAHLK1153DW, OAHlk1176DW, OAHLK1196DW, and OAHLK1256DW. The lowest dissolved oxygen concentration measured during the 5-year period at the seven sites was 2.5 mg/l, and occurred at site OAHLK1153DW in August 2007.

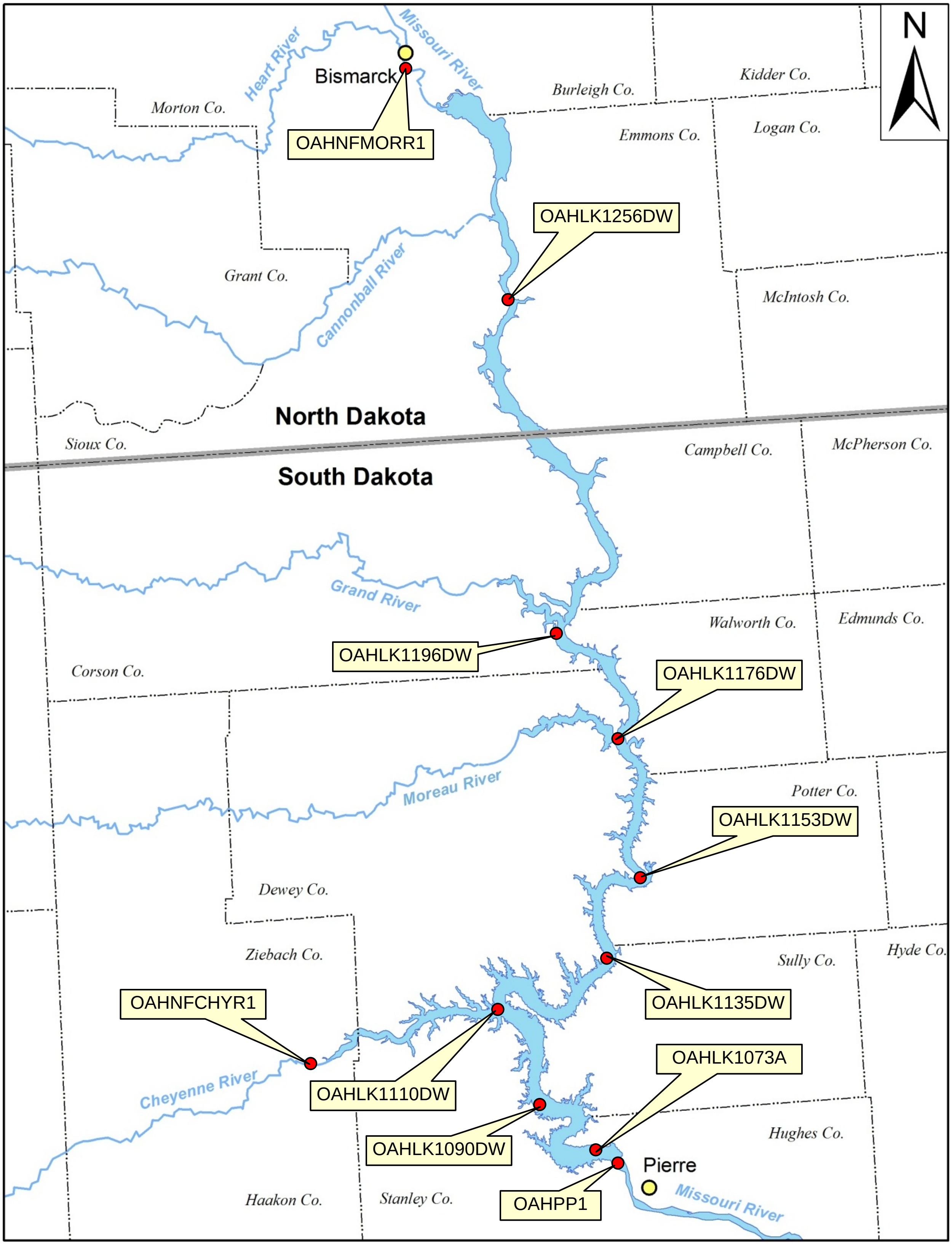

Figure 5-8. Location of sites where water quality monitoring was conducted by the District at the Oahe Project during the period 2005 through 2009.

5.4.2.1.2 Summer Thermal Stratification

5.4.2.1.2.1 Monthly Longitudinal Temperature Contour Plots

Summer thermal stratification of Lake Oahe during 2009 is described by the monthly longitudinal temperature contour plots based on depth-profile temperature measurements taken in May, June, July, August, and September (Plate 155, Plate 156, Plate 157, Plate 158, and Plate 159). The contour plots were constructed along the length of the reservoir. As seen in the contour plots, water temperature in Lake Oahe varies longitudinally from the dam to the reservoir's upper reaches and vertically from the reservoir surface to the bottom. The near-surface water in the upper reaches of the reservoir warms up sooner in the spring than the near-surface water near the dam (Plate 156). By mid-summer a strong thermocline becomes established in the lower reaches of the reservoir, and the near-surface waters of the entire reservoir above the thermocline are a fairly uniform temperature (Plate 158). As the near-surface waters of the reservoir cool in the late summer, the thermocline is pushed deeper and these wind-mixed upper waters are fairly uniform in temperature (Plate 159). The vertical variation in temperature is most prevalent in the deeper area of the reservoir towards the dam where a strong thermocline becomes established during the summer. The shallower upper reaches of Lake Oahe do not exhibit much vertical variation of temperature during mid to late summer as wind action allows for complete mixing of the water column.

5.4.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Lake Oahe at the deep water area near the dam is described by the depth-profile temperature plots measured over the 5-year period 2005 through 2009. Depth-profile temperature plots measured during the summer months were compiled (Plate 160). The plotted depth-profile measurements indicate that a significant temperature-depth gradient occurs in Lake Oahe in the near-dam lacustrine area during the summer, and a thermocline becomes established at a depth of 20 to 25 meters (Plate 160).

5.4.2.1.3 Summer Dissolved Oxygen Conditions

5.4.2.1.3.1 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen longitudinal contour plots were constructed along the length of Lake Oahe based on depth-profile measurements taken in May, June, July, August, and September of 2009 (Plate 161, Plate 162, Plate 163, Plate 164, and Plate 165). During the summer of 2009, dissolved oxygen conditions in Lake Oahe varied longitudinally from the dam to the reservoir's upper reaches and vertically from the reservoir surface to the bottom). Dissolved oxygen levels below 6 mg/l first appeared near the reservoir bottom in the middle reaches of the reservoir in July (Plate 163). As the summer progressed, dissolved oxygen concentrations below 6 mg/l expanded along the bottom in the middle reaches of the reservoir, but near-bottom dissolved oxygen concentrations at the dam remained above 6 mg/l (Plate 164 and Plate 165). The occurrence of low dissolved oxygen concentrations in the near-bottom water of the middle reaches of Lake Oahe is attributed to the increased allochthonous organic loading in the transition zone of the reservoir and the lesser hypolimnetic volume available for assimilation of the oxygen demand. As this material decomposes, a "pool" of water with low dissolved oxygen levels accumulates near the bottom in this area of the reservoir. Decomposition of autochthonous organic matter also occurs in the lacustrine zone and results in dissolved oxygen degradation as the summer progresses, although at a slower rate than what occurs in the transition zone. The recovery of near-bottom dissolved oxygen concentrations to saturation levels takes longer in the deeper water nearer the dam because of the time needed for thermal stratification to breakdown and mixing within the water column to occur in the deeper water.

5.4.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Lake Oahe at the deep-water area near the dam are described by the depth-profile dissolved oxygen plots measured over the 5-year period 2005 through 2009. Depth-profile dissolved oxygen plots measured during the summer months at site OAHLK1073A were compiled (Plate 166). Dissolved oxygen levels exhibited a gradient with depth and tended toward a negative heterograde to orthograde vertical distribution (Plate 166). During the 5-year period of 2005 through 2009, dissolved oxygen concentrations in the lower hypolimnion did not fall below 6 mg/l. The lowest dissolved oxygen concentration measured at this site over the past 5 years was 6.0 mg/l, which was measured at the reservoir bottom in September 2005.

5.4.2.1.4 Occurrence of Coldwater Permanent Fish Life Propagation Habitat in Lake Oahe

The most crucial period for the support of Coldwater Permanent Fish Life Propagation (CPFLP) habitat in Lake Oahe is when the reservoir begins to cool in late summer. As the thermocline moves deeper, the volume of the coldwater hypolimnion continues to decrease while the expanding epilimnion may not have cooled enough to be supportive of CPFLP habitat. At the same time, hypolimnetic dissolved oxygen concentrations are approaching their maximum degradation and low dissolved oxygen levels are moving upward from the reservoir bottom and "pinching off" coldwater habitat from below. This situation continues to worsen until the epilimnion cools enough to be supportive of CPFLP habitat and the reservoir eventually experiences fall turnover. The volume of the hypolimnion (i.e., CPFLP habitat) occurring in Lake Oahe during the summer decreases with lower pool levels.

The occurrence of CPFLP habitat (i.e., water temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l) in Lake Oahe was estimated from collected water temperature and dissolved oxygen depth-profile measurements and defined reservoir elevation and volume relationships. Plate 167 displays a plot of pool elevations and the CPFLP habitat estimated to have been present in Lake Oahe during the summers of 2005 through 2009.

The occurrence of coldwater habitat in Lake Oahe is highly dependent on pool elevation. Since coldwater habitat only occurs in the hypolimnion of the reservoir during the summer, the size of the hypolimnion will determine the amount of coldwater habitat potentially available. The upper extent of the hypolimnion is delineated by the thermocline (i.e., zone of rapid temperature decline) which separates the colder hypolimnion from the warmer, less dense water of the epilimnion. Depending on climatic factors, the thermocline in an individual reservoir will generally be established at a similar depth from year to year. Therefore, a greater hypolimnetic volume will tend to occur under higher pool elevations and a lesser hypolimnetic volume will tend to occur under lower pool elevations. The pool elevation in late-spring and early summer when the thermocline first becomes established is especially important as later changes in pool elevations are mitigated somewhat by the stratification already established. A larger hypolimnetic volume also has a greater assimilative capacity for oxygen demanding materials which can degrade dissolved oxygen levels in the hypolimnion below the CPFLP habitat standard of 6 mg/l.

The relationship between the occurrence of CPFLP habitat and pool elevation is can be seen in the CPFLP habitat estimated to have occurred in Lake Oahe during 2005 through 2009 (Plate 167). The year with the highest pool elevation (i.e., 2009) generally had the highest estimated occurrence of CPFLP habitat. The years with the lower pool elevations (i.e., 2005, 2006, 2007, and 2008) generally had the lowest estimated occurrence of CPFLP habitat. In late summer (i.e., September), the onset of fall turnover plays a significant role in the occurrence of CPFLP habitat in Lake Oahe. The year with the lowest pool elevation (i.e., 2006) had more estimated CPFLP in September than the year with the highest pool elevation (i.e., 2009) (Plate 167). This is attributed to fall turnover of Lake Oahe having completely occurred when monitored in 2006, and having incompletely occurred when monitored in 2009.

5.4.2.1.5 Water Clarity

5.4.2.1.5.1 Secchi Transparency

Figure 5-9 displays a box plot of the Secchi depth transparencies measured along Lake Oahe at the five sites OAHLK1256DW, OAHLK1196DW, OAHLK1153DW, OAHLK1110DW, and OAHLK1073A during the 5-year period 2005 through 2009. Secchi depth transparency increased in a downstream direction from the upper reaches of the reservoir to near the dam (Figure 5-9). This is attributed to suspended sediment in the inflowing Missouri River settling out in the reservoir as current velocities slow. The surface waters near Oahe Dam are significantly clearer than the upstream regions of the reservoir. Under the conditions that were monitored during the 2005 to 2009 period, it appears that sites OAHLK1256DW and OAHLK1196DW were in the riverine zone; site OAHLK1153DW was in the transition zone; site OAHLK1110DW was in the boundary area between the transition and lacustrine zones, and possibly impacted by the inflow of the Cheyenne River; and site OAHLK1073A was in the lacustrine zone of the reservoir.

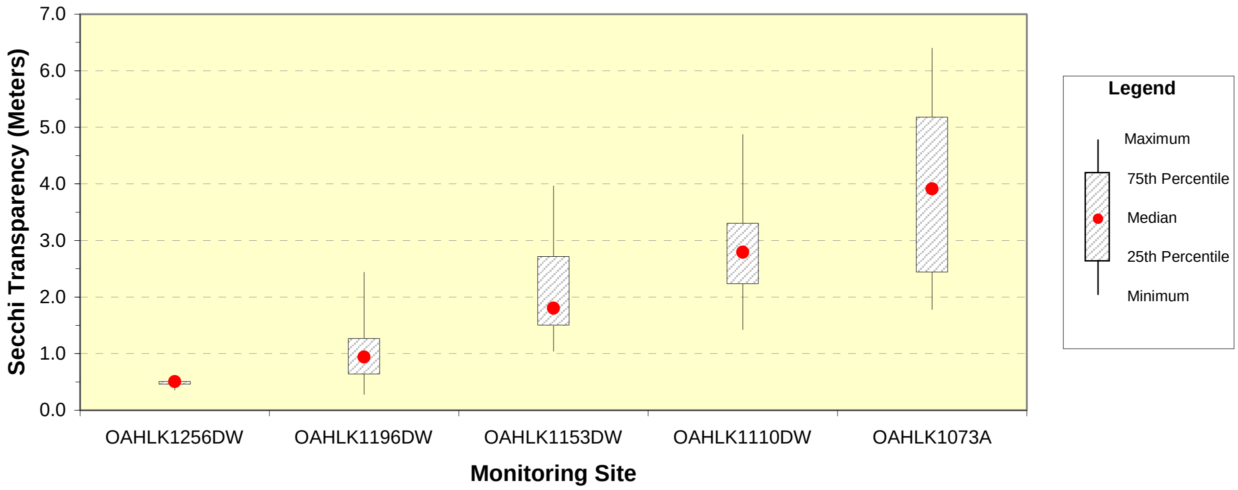

Figure 5-9. Box plot of Secchi transparencies measured in Lake Oahe during the 5-year period 2005 through 2009.

5.4.2.1.5.2 Turbidity

Monthly (i.e., May, June, July, August, and September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 during 2009 (Plate 168, Plate 169, Plate 170, Plate 171, and Plate 172). As seen in the contour plots, turbidity levels in Lake Oahe can vary longitudinally from the dam to the reservoir's upstream reaches. Turbidity levels measured in Lake Oahe did not exhibit appreciable vertical variation.

5.4.2.1.6 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Lake Oahe during the summer were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 1-meters of the reservoir bottom. The compared samples were collected at the near-dam site OAHLK1073A during the 5-year period 2005 through 2009. During the period a total of 22 paired samples were collected monthly from June through September. Box plots were constructed to display the

distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 173). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for water temperature, ORP, pH, and alkalinity. Parameters that were significantly lower in the near-bottom water of Lake Oahe included: water temperature ($p < 0.001$), and pH ($p < 0.001$). Parameters that were significantly higher in the near-bottom water included: ORP ($p < 0.001$) and alkalinity ($p < 0.001$).

5.4.2.1.7 Reservoir Trophic Status

Trophic State Index (TSI) values for Lake Oahe were calculated from monitoring data collected during the 5-year period 2005 through 2009 (Table 5-12). The calculated TSI values indicate that the lacustrine zone of the reservoir (i.e., sites OAHLK1073A and OAHLK1110DW) is mesotrophic, the transition zone (i.e., site OAHLK1153DW) is moderately eutrophic, and the riverine zone (i.e., sites OAHLK11961DW and OAHLK1256DW) is eutrophic. However, it is noted that the calculated average TSI value for the riverine zone is greatly influenced by the low water clarity in this part of the reservoir. This lack of water clarity is largely attributed to suspended inorganic material delivered to the reservoir by the Missouri River. Thus, the higher TSI values in the riverine zone seemingly are not indicative of increased algal growth associated with nutrient enrichment.

Table 5-12. Mean Trophic State Index (TSI) values calculated for Lake Oahe. TSI values are based on monitoring at the identified four sites during 5-year period 2005 through 2009.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
OAHLK1073A	41	51	44	46
OAHLK1110DW	45	54	43	47
OAHLK1153DW	51	56	50	52
OAHLK1196DW	64	55	54	58
OAHLK1256DW*	53	49	56	53

Note: See Section 4.1.4 for discussion of TSI calculation.
* Based on four monthly samples (i.e., June, July, August, and September) collected in 2009.

5.4.2.1.8 Phytoplankton Community

Phytoplankton grab samples collected from Lake Oahe at sites OAHLK10730A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, and OAHLK1256DW during the spring and summer of the 5-year period 2005 through 2009 are summarized in Plate 174, Plate 175, Plate 176, Plate 177, and Plate 178. The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The general prevalence of these taxonomic divisions in the reservoir were Bacillariophyta > Pyrrophyta > Chlorophyta/Cryptophyta > Chrysophyta/Cyanobacteria >> Euglenophyta. The Shannon-Weaver genera diversity indices calculated for the phytoplankton samples collected at the five sites over the 5-year period 2005 through 2009 ranged from 0.23 to 2.53 and averaged 1.47 at site OAHLK1073A, 1.54 at site OAHLK1110DW, 1.49 at site OAHLK1153DW, 1.56 at site OAHLK1196DW, and 1.74 at site OAHLK1256DW. Dominant

phytoplankton genera sampled at the five sites in 2009 (i.e., genera comprising more than 10% of the total biovolume of at least one sample collected in 2009) included the Bacillariophyta: *Asterionella, Aulacoseira, Cyclotella, Fragilaria, Stephanodiscus, Surirella, and Tablellaria*; Chlorophyta: *Cosmarium, Pediastrum, Pyramimonas,* and *Staurastrum*; Cryptophyta: *Cryptomonas* and *Rhodomonas*; Cyanobacteria: *Anabaena;* and Pyrrophyta: *Ceratium*. No concentrations of microcystin above 1 ug/l were monitored in Lake Oahe during the 5-year period 2005 through 2009.

5.4.2.1.9 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota's impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored in Lake Oahe during the 5-year period 2005 through 2009 did not indicate any impairment of designated water quality beneficial uses.

5.4.2.2 Water Quality Trends (1980 through 2009)

Water quality trends over the 30-year period of 1980 through 2009 were determined for Lake Oahe for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through September at the near-dam, ambient monitoring site (i.e., site OAHLK1073A). Plate 179 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, no significant trends were detected for Secchi depth, total phosphorus, or chlorophyll *a* (Plate 179). However, a slight increasing trend was detected for TSI ($p < 0.05$). Over the 30-year period, the reservoir has generally remained in a mesotrophic state (Plate 179).

5.4.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI RIVER INFLOW TO LAKE OAHE

5.4.3.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions that were monitored in the Missouri River at Bismarck, ND (i.e., site OAFNFMORR1) during the 5-year period 2005 through 2009 are summarized in Plate 180 and Plate 181. A review of these results indicated no major water quality concerns.

5.4.3.2 Missouri River Inflow Nutrient Flux Conditions

Nutrient flux rates for the Missouri River inflow to Lake Oahe over the 5-year period 2005 through 2009 were calculated based on near-surface water quality samples collected near Bismarck, ND (i.e. site OAHNFMORR1) and the instantaneous flow conditions at the time of sample collection (Table 5-13). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) are likely higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the flux rates given for total phosphorus and total organic carbon in Table 5-13 should be considered minimum estimates with the actual flux rates being higher. The maximum flux rates for all the constituents are believed to be attributed to higher nonpoint-source loadings during runoff conditions.

Table 5-13. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Bismarck, ND during April through September over the 5-year period 2005 through 2009.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	27	27	27	26	27	27	26
Mean	15,764	0.0118	0.1410	0.0311	0.0339	0.0087	1.2718
Median	15,500	0.0101	0.1437	0.0335	0.0144	n.d.	1.2217
Minimum	10,564	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	26,800	0.0530	0.3663	0.0632	0.1594	0.0780	2.2766

n.d. = Nondetectable.
Note: Nondetect values set to 0 for flux calculations.

5.4.3.3 Continuous Water Temperature Monitoring of the Missouri River at USGS Gage Site 06342500 at Bismarck, North Dakota

Through an agreement with the USGS, a water temperature monitoring probe was added to the USGS's gage (06342500) on the Missouri River near Bismarck, ND (i.e., site OAHNFMORR1). Beginning in 2005, water temperature measurements were recorded at the site. Plate 182, Plate 183, Plate 184, Plate 185, and Plate 186, respectively, plot mean daily water temperature and river discharge determined for 2005, 2006, 2007, 2008, and 2009.

5.4.4 WATER QUALITY AT THE OAHE POWERPLANT

5.4.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 187 and Plate 188 summarize the water quality conditions that were measured in samples collected from water discharged through Oahe Dam during 5-year period 2005 through 2009. A review of these results indicated possible water quality concerns regarding temperature for the support of Coldwater Permanent Fish Life Propagation.

5.4.4.2 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota's impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored at the Oahe powerplant during the 5-year period 2005 through 2009 indicate impairment of the designated Coldwater Permanent Fish Life Propagation water quality beneficial use.

Twenty-four percent of the "grab sample" water temperature measurements taken on the water passed through Oahe Dam exceeded the Coldwater Permanent Fish Life Propagation temperature criterion of 18.3°C. The exceedances of the temperature criterion occurred during the summer. In the summer when Lake Oahe is thermally stratified, water temperatures in the epilimnion of the reservoir regularly exceed 18.3°C, while temperatures in the hypolimnion are less than 18.3°C. Water discharged through Oahe Dam for power production is withdrawn from Lake Oahe at elevation 1524 ft-msl, approximately 114 feet above the reservoir bottom. Thus, water withdrawn from the reservoir in the summer, especially when pool elevations are lower due to drought conditions, can pull water down from the epilimnion. When water passed through Oahe Dam during the summer is withdrawn from the epilimnion of the reservoir, the temperature criterion of 18.3°C for the Missouri River and Big Bend

Reservoir just downstream of the dam are likely to be exceeded when Lake Oahe is thermally stratified. During 2009, pool elevations were near to above normal and only one sample collected at the Oahe powerplant in August exceeded the 18.3°C temperature criterion. Continuous water temperatures monitored at the Oahe powerplant during the past 5 years are shown in the time-series plots in the following section of this report.

5.4.4.3 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time-series plots for temperature, dissolved oxygen, and dam discharge monitored at the Oahe powerplant during the 5-year period 2005 through 2009 were constructed. Water temperatures showed seasonal warming and cooling through each calendar year (Plate 189 - Plate 198). Dissolved oxygen levels remained relatively high and stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall (Plate 199 - Plate 208). The lowest dissolved oxygen levels occurred during the late-summer period. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. The decreasing dissolved oxygen in the July to September period may also be attributed somewhat to the influence of ongoing degradation of dissolved oxygen in the hypolimnion as the summer progressed. Overall, there appeared to be minor correlation between discharge rates and measured water temperature and dissolved oxygen concentrations. However, there appeared to be more correlation between discharge and water temperature in the summer of 2009. In 2009 pool levels returned to normal after several years of prolonged drought. This resulted in the summer thermocline in Lake Oahe setting up at a higher elevation; above the intake elevation of the power tunnels. This seemingly resulted in colder water being drawn from the hypolimnion under lower discharges, and warmer water being drawn down from the epilimnion under higher discharges. In the drought years of 2005 through 2007 and the drought recovery year of 2008, discharge water temperatures in the summer regularly exceeded the coldwater permanent fish life protection criterion of 18.3°C. With the higher pool elevations in 2009, the overall water temperature of the Oahe Dam discharge was cooler during the summer and the 18.3°C criterion was exceeded less frequently.

5.4.4.4 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Lake Oahe

Plate 209, Plate 210, Plate 211, Plate 212, and Plate 213, respectively, plot the mean daily water temperatures monitored at the Missouri River near Bismarck, ND (site OAHNFMORR1) and the Oahe Dam powerplant (site OAHPP1) for 2005, 2006, 2007, 2008, and 2009. Inflow temperatures of the Missouri River to Lake Oahe are generally warmer than the outflow temperatures of Oahe Dam during the period of April through June. Outflow temperatures of the Oahe Dam discharge are generally warmer than the inflow temperatures of the Missouri River during the period of July through March. A maximum temperature difference occurs in the fall when the Oahe Dam outflow temperature is about 4°C warmer than the Missouri River inflow temperature.

5.4.4.5 Nutrient Flux Conditions of the Oahe Dam Discharge to the Missouri River

Nutrient flux rates for the Oahe Dam discharge to the Missouri River over the 5-year period 2005 through 2009 were calculated based on samples taken from the Oahe powerplant (i.e. site OAHPP1) and the dam discharge at the time of sample collection (Table 5-14). The samples collected in the powerplant are taken from the raw water supply line and are believed to be unbiased regarding particulate-associated constituents. Therefore, the flux rates calculated for the Oahe Dam discharge give an unbiased estimate of the flux rates for all the constituents, including total phosphorus and total organic carbon. The maximum flux rates for all the constituents are believed to be attributed to higher dam discharges.

Table 5-14. Summary of nutrient flux rates (kg/sec) calculated for the Oahe Dam discharge to the Missouri River (i.e., site OAHPP1) during January through December over the 5-year period 2005 through 2009.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	52	52	52	52	52	43	50
Mean	20,578	0.0219	0.2204	0.0136	0.0165	0.0076	1.7768
Median	20,997	n.d.	0.1835	n.d.	0.0115	n.d.	1.6513
Minimum	0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	51,658	0.1346	1.0239	0.1902	0.0759	0.0345	4.5345

Note: Nondetectable values set to 0 for flux calculations.

5.5 BIG BEND

5.5.1 BACKGROUND INFORMATION

5.5.1.1 Project Overview

Big Bend Dam is located in central South Dakota on the Missouri River at RM 987.4, 21 miles northwest of Chamberlain, SD. The closing of Big Bend Dam in 1963 resulted in the formation of Big Bend Reservoir (Lake Sharpe). The reservoir, when full, is 80 miles long, covers 61,000 acres, and has 200 miles of shoreline. Table 5-15 summarizes how the surface area, volume, mean depth, and retention time of Lake Sharpe vary with pool elevations. The Big Bend powerplant is operated to meet peak power demands for electricity. Generally, weekly flows from Oahe Dam are released at Big Bend Dam, and there is minimal fluctuation in the water level of Lake Sharpe. The Annual Flood Control and Multiple Use Zone in the reservoir does not provide for seasonal regulation of flood inflows like the other major upstream Mainstem System projects, but the zone is used for day-to-day and week-to-week power operations. The Corps normally strives to maintain the pool level in the reservoir between elevation 1419 ft-msl and 1421.5 ft-msl. There are no minimum flow requirements below Big Bend Dam, and hourly releases can fluctuate from 0 to 110,000 cfs for peaking power generation. The major inflows to Lake Sharpe are the Missouri River and Bad River. Water discharged through Big Bend Dam for power production is withdrawn from the bottom of Lake Sharpe at an invert elevation of 1330.0 ft-msl. Figure 5-10 shows a schematic drawing of the powerplant intake structure at Big Bend Dam.

The reservoir and dam are authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Over the period 1967 through 2009, the eight generating units at Big Bend Dam produced an annual average 0.969 million mega-watt hours (MWh) of electricity, which has a current revenue value of approximately $16 million. Past drought conditions in the interior western United States has curtailed releases and power production at the Missouri River mainstem system projects, including Big Bend. Power production at the Big Bend Dam generating units averaged an annual 0.585 MWh over the 5-year period 2005 through 2009. Habitat for one endangered species, interior least tern, and one threatened species, piping plover, occurs within the project area. Three surface water intakes are located in Lake Sharpe: Mni Wiconi Rural Water System (RM1070 – 12 counties and Lower Brule, Rosebud, and Pine Ridge Indian Reservations); Lower Brule Rural Water System (RM993 – Lower Brule); and Fort Thompson Rural Water Service (RM987 – Fort Thompson). The reservoir is an important recreational resource.

Table 5-15. Surface area, volume, mean depth, and retention time of Lake Sharpe at different pool elevations based on 1997 survey.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1430	70,615	2,259,568	32.0	0.1344
1425	63,808	1,923,508	30.1	0.1144
1420	57,007	1,621,484	28.4	0.0965
1415	50,224	1,353,339	26.9	0.0805
1410	43,146	1,119,548	25.9	0.0666
1405	35,694	923,872	25.9	0.0550
1400	31,842	756,297	23.8	0.0450
1395	27,402	608,587	22.2	0.0362
1390	24,659	479,172	19.4	0.0285
1385	21,779	362,729	16.7	0.0216
1380	18,307	262,285	14.3	0.0156
1375	14,856	179,548	12.1	0.0107
1370	11,747	113,160	9.6	0.0067
1365	8,590	62,333	7.3	0.0037
1360	5,449	27,069	5.0	0.0016
1355	2,021	9,373	4.6	0.0006
1350	836	2,445	2.9	0.0001

Average Annual Inflow (1967 through 2009) = 16.99 Million Acre-Feet.
Average Annual Outflow: (1967 through 2009) = 16.81 Million Acre-Feet.
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1423-1422 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 1422-1420 ft-msl), Carryover Multiple Use Zone (none), and Permanent Pool Zone (elev. 1420-1345 ft-msl). All elevations are in the NGVD 29 datum.

Figure 5-10. Diagrammatic drawing of powerplant intake structure at Big Bend Dam.

5.5.1.2 Water Quality Standards Classification and Section 303(d) Listings

5.5.1.2.1 Lake Sharpe

South Dakota has classified the Missouri River impoundments within the State as flowing streams and not reservoirs (South Dakota Administrative Rules 74:51:01:43). The following water quality-dependent beneficial uses have been designated for Lake Sharpe in South Dakota's water quality standards: domestic water supply waters, coldwater permanent fish life propagation waters, immersion recreation waters, limited-contact recreation waters, commerce and industry waters, agricultural water supply (i.e., irrigation and stock watering), and fish and wildlife propagation. The State of South Dakota has recently removed Lake Sharpe from the State's Section 303(d) list of impaired waters. The reservoir was previously listed as impaired due to accumulated sediment from the Bad River watershed. A total maximum daily load (TMDL) was developed and is being implemented to address this concern, resulting in the delisting of Lake Sharpe. South Dakota has not issued a fish consumption advisory for the reservoir.

5.5.1.2.2 Missouri River Downstream of Big Bend Dam

The State of South Dakota has designated the following water quality-dependent beneficial uses for the Missouri River downstream of Big Bend Dam: domestic water supply waters, warmwater permanent fish life propagation waters, immersion recreation waters, limited-contact recreation waters, commerce and industry waters, agricultural water supply (i.e., irrigation and stock watering), and fish and wildlife propagation. Big Bend Dam is the demarcation point between coldwater and warmwater use designation on the Missouri River system in South Dakota. Therefore, the designated use of Warmwater Permanent Fish Life Propagation applies to the Big Bend Dam tailwaters instead of the Coldwater Permanent Fish Life Propagation use that applies to Lake Sharpe. South Dakota has not issued a fish consumption advisory for the Missouri River downstream of Big Bend Dam.

5.5.1.2.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at the Big Bend Project since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow to and outflow from the reservoir. A 3-year intensive water quality survey was initiated in 2008 and is currently underway at the Big Bend Project. The water quality conditions of the Oahe Dam discharge are taken to represent the inflow water quality conditions of the Missouri River to Lake Sharpe. Figure 5-11 shows the location of sites at the Big Bend Project that have been monitored for water quality during the past 5 years (i.e., 2005 through 2009). The near-dam location (i.e., site BBDLK0987A) has been continuously monitored since 1980.

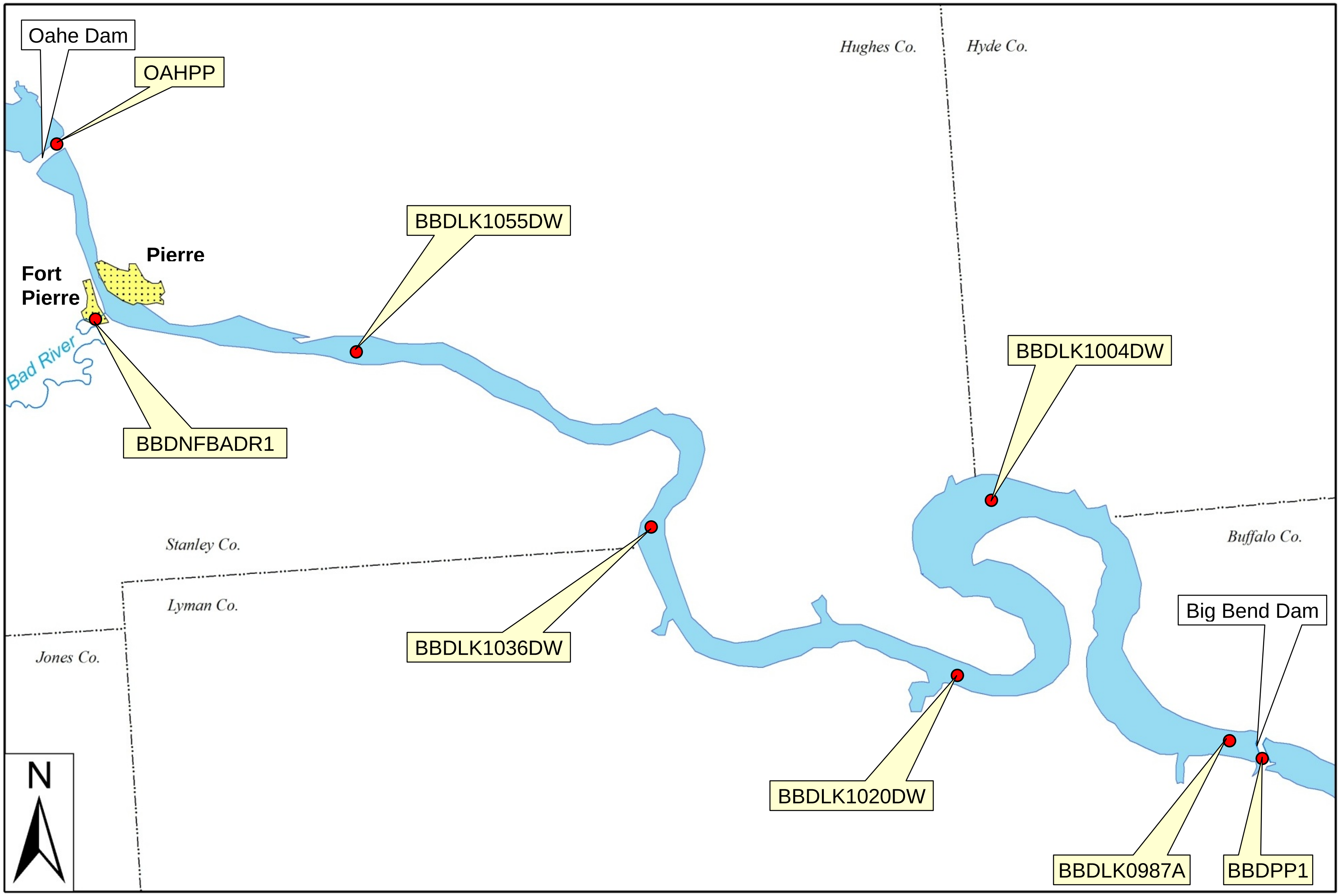

Figure 5-11. Location of sites where water quality monitoring was conducted by the District at the Big Bend Project during the 5-year period 2005 through 2009.

5.5.2 WATER QUALITY IN LAKE SHARPE

5.5.2.1 Existing Water Quality Conditions

5.5.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Lake Sharpe at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, and BBDLK1005DW from May through September during the 5-year period 2005 through 2009 are summarized in Plate 214, Plate 215, Plate 216, Plate 217, and Plate 218. A review of these results indicated water quality concerns regarding water temperature and dissolved oxygen for the support of Coldwater Permanent Fish Life Propagation (CPFLP). Due to its shallowness, a hypolimnion rarely forms in Lake Sharpe and water temperatures throughout the reservoir regularly exceed 18.3°C in the summer. Dissolved oxygen levels near the bottom of the reservoir occasionally fall below 6.0 mg/l CPFLP criterion during the summer. The lowest dissolved oxygen concentration measured during the 5-year period at the five sites was 3.1 mg/l, and occurred near the dam at site BBDLK0987A in July 2005.

5.5.2.1.2 Summer Thermal Stratification

5.5.2.1.2.1 Monthly Longitudinal Temperature Contour Plots

Summer thermal stratification of Lake Sharpe during 2009 is described by the monthly longitudinal temperature contour plots based on depth-profile temperature measurements taken in June, July, August, and September (Plate 219, Plate 220, Plate 221, and Plate 222). The contour plots were constructed along the length of the reservoir. As seen in the contour plots, water temperature in Big Reservoir varies longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Cooler water is typically discharged from Oahe Dam from late-spring through mid-summer which quickly warms in Lake Sharpe. Although some summer thermal stratification of Lake Sharpe can occur, the relative shallowness, short retention time, and bottom withdrawal of the reservoir seemingly inhibit the formation of a strong thermocline and long-lasting stratification during the summer.

5.5.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Lake Sharpe at the deep water area near the dam is described by the depth-profile temperature plots measured over the 5-year period 2005 through 2009. Depth-profile temperature plots measured during the summer months were compiled (Plate 223). No significant temperature-depth gradient is apparent in Lake Sharpe in the near-dam area during the summer (Plate 223).

5.5.2.1.3 Summer Dissolved Oxygen Conditions

5.5.2.1.3.1 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen longitudinal contour plots were constructed along the length of Lake Sharpe based on depth-profile measurements taken in June, July, August, and September of 2009 (Plate 224, Plate 225, Plate 226, and Plate 227). During the summer of 2009, dissolved oxygen conditions in Lake Sharpe varied longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Dissolved oxygen levels below 6 mg/l were only monitored in July at the reservoir bottom near the dam (Plate 225).

5.5.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Lake Sharpe at the deep-water area near the dam are described by the depth-profile dissolved oxygen plots measured over the 5-year period 2005 through 2009. Depth-profile dissolved oxygen plots measured during the summer months at site BBDLK0987A were compiled (Plate 228). Dissolved oxygen levels below 6 mg/l regularly occurred near the bottom of the reservoir, and levels near the reservoir bottom approached 3 mg/l on two occasions.

5.5.2.1.4 Occurrence of Coldwater Permanent Fish Life Propagation Habitat in Lake Sharpe

The most crucial period for the support of Coldwater Permanent Fish Life Propagation (CPFLP) habitat in Lake Sharpe is during mid-summer. Monitoring indicates that the reservoir is probably discontinuous polymictic with a hypolimnion only forming on an irregular basis. This results in complete mixing and warming of the water column above 18.3°C during the summer. When stratification does persist, dissolved oxygen degradation to levels below 6 mg/l occurs near the reservoir bottom in deeper waters near the dam.

The occurrence of CPFLP habitat (i.e., water temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l) in Lake Sharpe was estimated from collected water temperature and dissolved oxygen depth-profile measurements. Conditions supportive of CPFLP were present in 40, 14, 37, 57, and 50 percent of the depth-profile measurements respectively taken at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, and BBDLK1005DW during the 5-year period 2005 through 2009 (Plate 214 - Plate 218). Conditions supportive of CPFLP are rarely present anywhere in the reservoir during the months of July and August. Ambient water temperatures in Lake Sharpe do not appear to be cold enough to support CPFLP, as defined by State water quality criteria, during mid-summer. Consideration should be given to reclassify the reservoir for a Warmwater Permanent Fish Life Propagation use based on a use attainability assessment of "natural conditions" regarding ambient water temperatures.

5.5.2.1.5 Water Clarity

5.5.2.1.5.1 Secchi Transparency

Figure 5-12 displays a box plot of the Secchi depth transparencies measured along Lake Sharpe at the five sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW, and Oahe Dam tailwaters during the 2-year period 2008 through 2009. The Secchi depth of the Oahe Dam tailwaters was taken to be the Secchi depth measured in Lake Oahe at the near-dam monitoring site (i.e., OAHLK1073A). Secchi depth transparency decreased significantly in the upstream reaches of Lake Sharpe (Figure 5-12). This pronounced decrease in transparency is attributed to turbid runoff from the Bad River and sedimentation in the upstream reaches of the reservoir attributed to the Bad River. The "light" nature of these sediments and the shallowness of Lake Sharpe in its upstream reaches allows for wind action to continually re-suspend deposited sediment in this area of the reservoir.

5.5.2.1.5.2 Turbidity

Monthly (i.e., June, July, August, and September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1005DW, and OAHPP1 during 2009 (Plate 229, Plate 230, Plate 231, and Plate 232). As seen in the contour plots, turbidity levels measured in Lake Sharpe during 2009 varied longitudinally from the dam to the reservoir's upstream reaches; especially in August (Plate 231). The Bad River inflow and sedimentation delta seemingly have a pronounced impact on turbidity in the upstream reaches of Lake Sharpe.

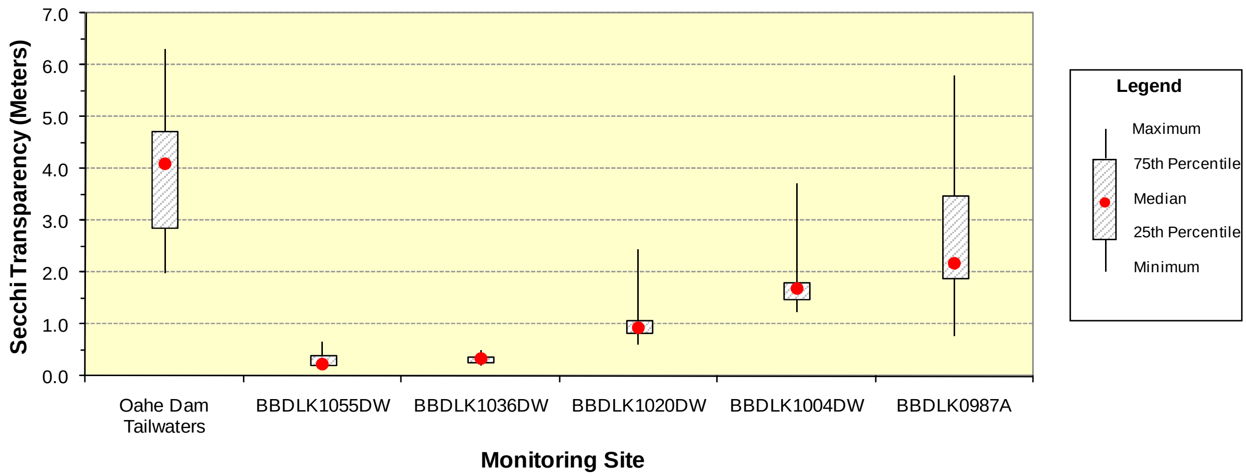

Figure 5-12. Box plot of Secchi transparencies measured in Lake Sharpe during the 2-year period 2008 through 2009.

5.5.2.1.6 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Lake Sharpe during the summer were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 1-meter of the reservoir bottom. The compared samples were collected at the near-dam site BBDLK0987A during the 5-year period 2005 through 2009. During the period a total of 20 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 233). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for water temperature, dissolved oxygen, ORP, pH, and TKN. Parameters that were significantly lower in the near-bottom water of Lake Sharpe included: water temperature ($p < 0.001$), dissolved oxygen ($p < 0.001$), and pH ($p < 0.01$). Parameters that were significantly higher in the near-bottom water included: ORP ($p < 0.01$) and TKN ($p < 0.05$).

5.5.2.1.7 Reservoir Trophic Status

Trophic State Index (TSI) values for Lake Sharpe were calculated from monitoring data collected during the 2-year period 2008 through 2009 (Table 5-16). The calculated TSI values indicate that the area near the dam (i.e., site BBDLK0987A) is mesotrophic to moderately eutrophic, the middle reaches of the reservoir (i.e., site BBDLK1020DW) is eutrophic, and the upstream reaches of the reservoir (i.e., site BBDLK1055DW) is eutrophic to borderline hypereutrophic. However, it is noted that the calculated average TSI value for the upstream reaches is greatly influenced by the low water clarity in this part of the reservoir. This lack of water clarity is largely attributed to suspended inorganic material delivered to the reservoir by the Bad River. Thus, the higher TSI values in the upstream reaches may not be indicative of increased algal growth associated with nutrient enrichment.

Table 5-16. Mean Trophic State Index (TSI) values calculated for Lake Sharpe. TSI values are based on monitoring at the identified three sites during the 2-year period 2008 through 2009.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
BBDLK0987A	45	47	56	50
BBDLK1020DW	60	52	60	57
BBDLK1055DW	78	59	57	65

Note: See Section 4.1.4 for discussion of TSI calculation.

5.5.2.1.8 Phytoplankton Community

Phytoplankton grab samples collected from Lake Sharpe at sites BBDLK0987A, BBDLK1020DW, and BBDLK1055DW during the spring and summer of the 5-year period 2005 through 2009 are summarized in Plate 234, Plate 235, and Plate 236. The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The general prevalence of these taxonomic divisions in the reservoir, based on taxa occurrence, were Bacillariophyta > Chlorophyta > Cyanobacteria > Cryptophyta/Pyrrophyta > Chrysophyta > Euglenophyta. The diatoms were generally the most abundant algae based on percent composition. The Shannon-Weaver genera diversity indices calculated for the 41 phytoplankton samples collected at the three sites ranged from 0.16 to 2.74 and averaged 1.58 at site BBDLK0987A, 1.50 at site BBDLK1020DW, and 1.65 at site BBDLK1055DW. Dominant phytoplankton genera sampled at the three sites in 2009 (i.e., genera comprising more than 10% of the total biovolume of at least one sample collected in 2009) included the Bacillariophyta *Asterionella*, *Aulacoseira*, *Cymbella*, *Diatoma*, *Fragilaria*, *Melosira*, *and Tablellaria*; Chlorophyta *Pyramimonas*; Cryptophyta *Cryptomonas and Rhodomonas*; and Pyrrophyta *Ceratium*. No concentrations of the Cyanobacteria microcystin toxin above 1 ug/l were monitored at sites BBDLK0987A, BBDLK1020DW, or BBDLK1055DW during 2005 through 2009.

5.5.2.1.9 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota's impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored in Lake Sharpe during the 5-year period 2005 through 2009 indicate that the designated Coldwater Permanent Fish Life Propagation use is not being attained due to warm water temperatures. Consideration should be given to reclassify the reservoir for a Warmwater Permanent Fish Life Propagation use based on a use attainability assessment of "natural conditions" regarding ambient water temperatures.

5.5.2.2 Water Quality Trends (1980 through 2009)

Water quality trends over the 30-year period of 1980 through 2009 were determined for Lake Sharpe for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam, ambient monitoring site (i.e., site BBDLK0987A). Plate 237 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Lake Sharpe exhibited significant trends for Secchi depth (decreasing) and TSI (increasing) (Plate 237). No significant trend was detected for total phosphorus and chlorophyll *a* (Plate 237). Over the 30-year period, the reservoir has generally remained mesotrophic to moderately eutrophic (Plate 237).

5.5.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI AND BAD RIVER INFLOWS TO LAKE SHARPE

5.5.3.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions of the Missouri River inflow to Lake Sharpe is taken to be the monitored water quality conditions of the outflow from Oahe Dam. See Plate 187 and Plate 188 for a summary of the water quality conditions monitored on the water discharged from Oahe Dam. The water quality conditions of the Bad River inflow to Lake Sharpe monitored at site BBDNFBADR1 during the 2-year period 2008 through 2009 are summarized in Plate 238.

5.5.3.2 Missouri River Inflow Nutrient Flux Conditions

Nutrient flux rates for the Missouri River inflow to Lake Sharpe over the last 5 years were calculated based on water quality conditions monitored on water discharged through Oahe Dam (i.e. site OAHPP1) (Table 5-17). The samples collected in the Oahe powerplant are taken from the raw water supply line and are believed to be unbiased regarding particulate-associated constituents. Therefore, the flux rates calculated for the Oahe Dam discharge give an unbiased estimate of the flux rates for all the constituents, including total phosphorus and total organic carbon. The maximum flux rates for all the constituents are believed to be attributed to higher dam discharges.

Table 5-17. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Oahe Dam (i.e., site OAHPP1) over the 5-year period 2005 through 2009.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	52	52	52	52	52	43	50
Mean	20,578	0.0219	0.2204	0.0136	0.0165	0.0076	1.7768
Median	20,997	n.d.	0.1835	n.d.	0.0115	n.d.	1.6513
Minimum	0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	51,658	0.1346	1.0239	0.1902	0.0759	0.0345	4.5345

n.d. = Nondetectable.
Note: Nondetect values set to 0 for flux calculations.

5.5.3.3 Mean Daily Discharge and Temperature

Mean daily discharge and water temperature of the Oahe Dam outflow was determined for the past 5 years. These are considered the water quality conditions of the Missouri River inflow to Lake Sharpe. Plate 239, Plate 240, Plate 241, Plate 242, and Plate 243, respectively, plot 2005, 2006, 2007, 2008, and 2009 mean daily water temperature and flow for the Oahe Dam discharge.

5.5.4 WATER QUALITY AT THE BIG BEND DAM POWERPLANT

5.5.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 244 and Plate 245 summarize the water quality conditions that were monitored on water discharged through Big Bend Dam during the 5-year period 2005 through 2009. A review of these results seemingly found no significant water quality concerns. However, the 0.18 ug/l human health criterion for total arsenic was exceeded on all three occasions. The highest total arsenic concentration measured was 2 ug/l (Plate 245).

5.5.4.2 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota's impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored at the Big Bend powerplant during the 5-year period 2005 through 2009 did not indicate any impairment of designated water quality beneficial uses.

5.5.4.3 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time-series plots for temperature, dissolved oxygen, and dam discharge monitored at the Big Bend powerplant during the 5-year period 2005 through 2009 were constructed. Water temperatures showed seasonal warming and cooling through each calendar year (Plate 246 - Plate 255). Dissolved oxygen levels remained relatively high and fairly stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall (Plate 256 - Plate 265). The lowest dissolved oxygen levels occurred during the July to August period. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. There appeared to be significant correlation between discharge rates and water temperature and dissolved oxygen concentrations measured during the summer months. The lower dissolved oxygen concentrations monitored in the summer may be attributed to periodic stratification and the degradation of dissolved oxygen conditions near the bottom of the reservoir. Since the inlet to the powerhouse is located at the reservoir bottom, lower flows through the dam may result in more "laminar" flow that pulls in water with degraded dissolved oxygen conditions along the bottom into the powerplant.

5.5.4.4 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Lake Sharpe

Plate 266, Plate 267, Plate 268, Plate 269, and Plate 270, respectively, plot the mean daily water temperatures monitored for the Missouri River at Oahe Dam (site OAHPP1) and the Big Bend Dam powerplant (site BBDPP1) for 2005, 2006, 2007, 2008, and 2009. Inflow temperatures of the Missouri River to Lake Sharpe are about 4°C warmer than the outflow temperatures of Big Bend Dam during the fall. Outflow temperatures of the Big Bend Dam discharge are about 3°C warmer than the inflow temperatures of the Missouri River during the spring, summer, and fall.

5.5.4.5 Nutrient Flux Conditions of the Big Bend Dam Discharge to the Missouri River

Nutrient flux rates for the Big Bend Dam discharge to the Missouri River over the 5-year period 2005 through 2009 were calculated based on samples taken from the Big Bend powerplant (i.e. site BBDPP1) and the dam discharge at the time of sample collection (Table 5-18). The samples collected in the powerplant are taken from the raw water supply line and are believed to be unbiased regarding particulate-associated constituents. Therefore, the flux rates calculated for the Big Bend Dam discharge give an unbiased estimate of the flux rates for all the constituents, including total phosphorus and total organic carbon. The maximum flux rates for all the constituents are believed to be attributed to higher dam discharges.

Table 5-18. Summary of nutrient flux rates (kg/sec) calculated for the Big Bend Dam discharge to the Missouri River (i.e., site BBDPP1) during January through December over the 5-year period 2005 through 2009.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	51	51	51	51	51	39	50
Mean	25,568	0.0302	0.3446	0.0141	0.0196	0.0084	2.2490
Median	23,271	n.d.	0.2676	n.d.	0.0132	n.d.	2.1159
Minimum	0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	71,980	0.1883	1.2197	0.2662	0.1150	0.0468	6.1146

Note: Nondetectable values set to 0 for flux calculations.

5.6 FORT RANDALL

5.6.1 BACKGROUND INFORMATION

5.6.1.1 Project Overview

Fort Randall Dam is located on the Missouri River at RM 880.0 in southeastern South Dakota, 50 miles southwest of Mitchell, SD. The closing of Fort Randall Dam in 1952 resulted in the formation of Fort Randall Reservoir (Lake Francis Case). When full, the reservoir is 107 miles long, covers 102,000 acres, and has 540 miles of shoreline. Table 5-19 summarizes how the surface area, volume, mean depth, and retention time of Lake Francis Case vary with pool elevations. The reservoir at the end of December 2009 was at pool elevation 1339.7 ft-msl. This is 10.3 feet below the top of the Carryover Multiple Use Zone (1350.0 ft-msl). A "low" pool level is typical for Lake Francis Case at the end of December because this reservoir is drawn down each fall to provide storage space for high winter power releases from Oahe and Big Bend. Major inflows to Lake Francis Case are the Missouri River and White River. Water discharged through Fort Randall Dam for power production is withdrawn from Lake Francis Case at elevation 1229 ft-msl, approximately 2 feet above the reservoir bottom. Figure 5-13 shows a schematic drawing of the outlet works at Fort Randall Dam.

Lake Francis Case was authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Over the period 1967 through 2009, the eight generating units at Fort Randall Dam have produced an annual average 1.73 million mega-watt hours (MWh) of electricity, which has a current revenue value of approximately $28 million. The recent drought in the western United States curtailed releases and power production at the Mainstem System projects, including Fort Randall. Power production at the Fort Randall Dam generating units averaged an annual 1.11 MWh over the 5-year period 2005 through 2009. Habitat for two endangered species, pallid sturgeon and interior least tern, and one threatened species, piping plover, occur within the project area. Five surface water intakes are located in Lake Sharpe: 1) Chamberlain, SD (RM967); 2) Aurora-Brule Rural Water System (RM966 – Pukwana, Kimball, White Lake, Stickneym, Plankington, Gann Valley, Aurora Center, SD, and approximately 1,000 farms); 3) Oacoma, SD (RM967); and 4 and 5) Randall Community Water District - Platte and Pickstown (RM912 and RM880 – Pickstown, Davidson, Charles Mix, and Douglas, SD. The reservoir is an important recreational resource and a major visitor destination in South Dakota.

Table 5-19. Surface area, volume, mean depth, and retention time of Lake Francis Case at different pool elevations based on 1996 survey.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1370	98,438	4,916,698	49.9	0.279
1365	94,801	4,433,011	46.7	0.251
1360	89,808	3,971,266	44.2	0.225
1355	85,453	3,531,526	41.3	0.200
1350	76,747	3,124,368	40.7	0.177
1345	68,588	2,761,139	40.3	0.157
1340	59,783	2,439,591	40.8	0.138
1335	50,547	2,165,606	42.8	0.123
1330	45,845	1,926,136	42.0	0.109
1325	40,277	1,711,773	42.5	0.097
1320	37,911	1,517,486	40.0	0.086
1315	35,000	1,335,568	38.2	0.076
1310	33,632	1,164,645	34.6	0.066
1305	32,119	1,000,024	31.1	0.057
1300	30,297	843,949	27.9	0.048
1295	28,608	696,350	24.3	0.039
1290	26,042	559,475	21.5	0.032

Average Annual Inflow (1967 through 2009) = 17.89 Million Acre-Feet.
Average Annual Outflow: (1967 through 2009) = 17.63 Million Acre-Feet.
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1375-1365 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 1365-1350 ft-msl), Carryover Multiple Use Zone (1350-1320 ft-msl), and Permanent Pool Zone (elev. 1320-1227 ft-msl). All elevations are in the NGVD 29 datum.

5.6.1.2 <u>Water Quality Standards Classification and Section 303(d) Listings</u>

5.6.1.2.1 Lake Francis Case

South Dakota has classified the Missouri River impoundments within the State as flowing streams and not reservoirs (South Dakota Administrative Rules 74:51:01:43). The State of South Dakota has designated the following water quality-dependent beneficial uses for Lake Francis Case in the State's water quality standards: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of South Dakota has not placed Lake Francis Case on the State's Section 303(d) list of impaired waters and has not issued a fish consumption advisory for the reservoir.

5.6.1.2.2 Fort Randall Dam Tailwaters

South Dakota's water quality standards designate the following beneficial uses for the Missouri River downstream of Fort Randall Dam: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of South Dakota has not placed the Missouri River downstream of Fort Randall Dam on the State's Section 303(d) list of impaired waters and has not issued a fish consumption advisory for the river.

Figure 5-13. Schematic drawing and photo of outlet works at Fort Randall Dam.

5.6.1.2.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at the Fort Randall Project since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow to and outflow from the reservoir. The water quality conditions of the Big Bend Dam discharge are taken to represent the inflow water quality conditions of the Missouri River to Lake Francis Case. A 3-year intensive water quality survey was completed at the Fort Randall Project in 2008, and the findings of the intensive survey are available in the separate report, "Water Quality Conditions Monitored at the Corps' Fort Randall Project in South Dakota during the 3-Year period 2006 through 2008" (USACE, 2009b). Figure 5-14 shows the location of sites at the Fort Randall Project that have been monitored for water quality during the past 5 years (i.e., 2004 through 2008). The near-dam location (i.e., site FTRLK0880A) has been continuously monitored since 1980.

5.6.2 WATER QUALITY IN LAKE FRANCIS CASE

5.6.2.1 Existing Water Quality Conditions

5.6.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Lake Francis Case at sites FTRLK0880A, FTRLK0892DW, FTRLK0911DW, FTRLK0924DW, FTRLK0940DW, FTRLK0955DW, and FTRLK0968DW from May through September during the 5-year period 2005 through 2009 are summarized in Plate 271, Plate 272, Plate 273, Plate 274, Plate 275, Plate 276, and Plate 277. A review of these results indicated possible water quality concerns regarding dissolved oxygen and suspended solids for the support of Warmwater Permanent Fish Life Propagation. Dissolved oxygen levels in the hypolimnion degrade along the reservoir bottom as summer progresses and fall below 5.0 mg/l in July and August. The lowest dissolved oxygen concentration measured at the seven sites was 0.1 mg/l and occurred at the reservoir bottom at site FTRLK0955DW in June 2008. The chronic suspended solids criterion was exceeded in Lake Francis Case in the area near the confluence of the White River (Plate 275).

5.6.2.1.2 Summer Thermal Stratification

5.6.2.1.2.1 Monthly Longitudinal Temperature Contour Plots

Summer thermal stratification of Lake Francis Case during 2009 is described by the monthly longitudinal temperature contour plots based on depth-profile temperature measurements taken in May, June, July, August, and September (Plate 278, Plate 279, Plate 280, Plate 281, and Plate 282). The contour plots were constructed along the length of the reservoir. As seen in the contour plots, water temperature in Lake Francis Case varies longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Water temperatures in the upstream reaches of the reservoir are influenced by the discharges from Big Bend Dam (RM987) and inflows from the White River (RM956). It appears that inflows from the White River tend to locally warm Lake Francis Case in the spring and early-summer (Plate 279 and Plate 280). In late-spring to mid-summer an appreciable vertical thermal gradient was present in the lacustrine, downstream region of the reservoir. By late summer this vertical thermal gradient had greatly diminished greatly.

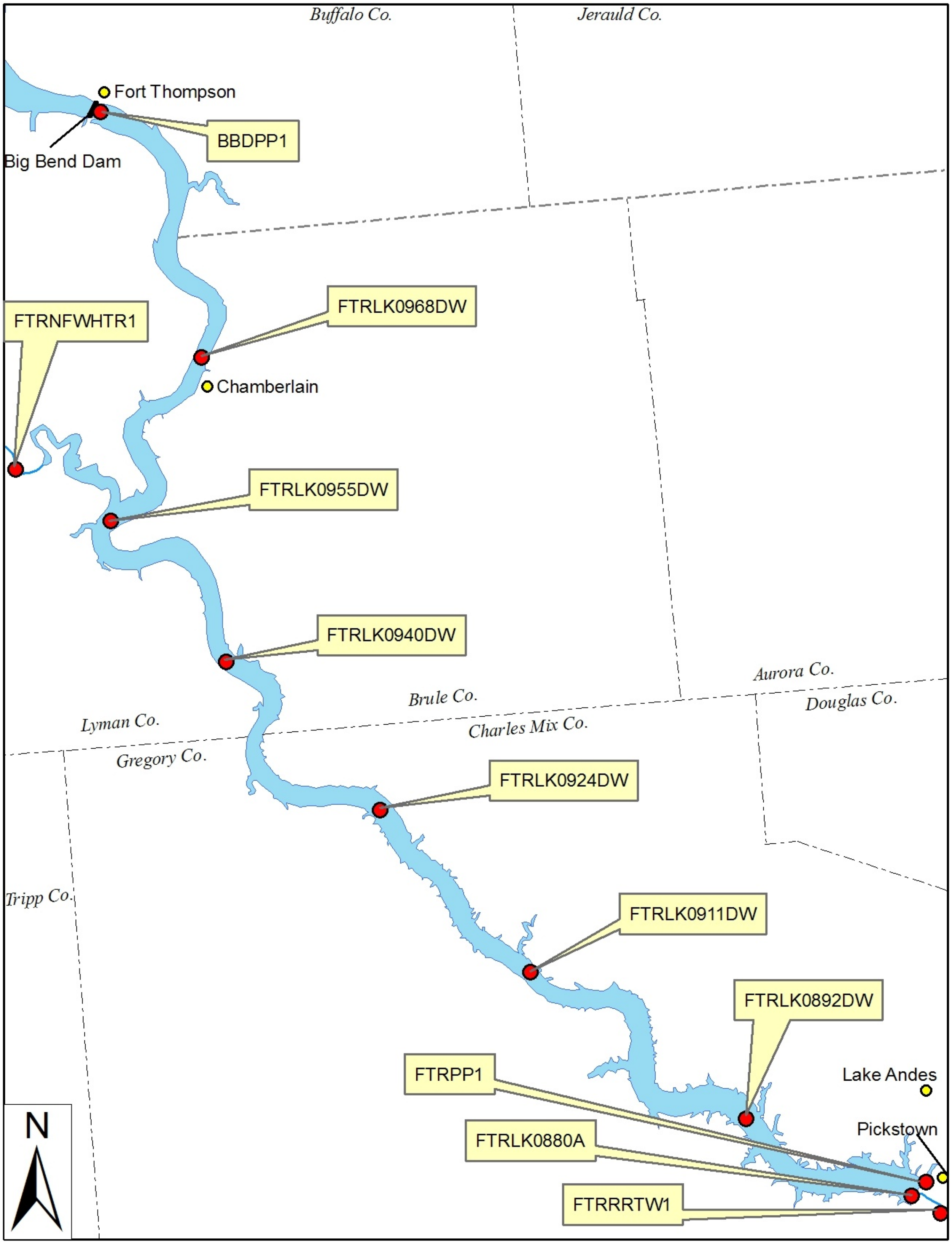

Figure 5-14. Location of sites where water quality monitoring was conducted by the District at the Fort Randall Project during the 5-year period 2005 through 2009.

5.6.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Lake Francis Case in the deep water area near the dam is described by the depth-profile temperature measurements taken over the 5-year period 2005 through 2009. Depth-profile temperatures measured during the summer months at site FTRLK0880A were compiled and plotted (Plate 283). The depth-profile temperature plots indicate that a moderate temperature-depth gradient occasionally occurred in the summer in the deeper area of Lake Francis Case near the dam, and a significant thermocline developed at a depth of about 20 to 25 meters. Thermal stratification breaks down in late summer as water column mixing is seemingly induced by reservoir drawdown, warming of the hypolimnion, and bottom withdrawals from the reservoir.

5.6.2.1.3 Summer Dissolved Oxygen Conditions

5.6.2.1.3.1 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen contour plots were constructed along the length of Lake Francis Case based on depth-profile measurements taken in May, June, July, August, and September of 2009 (Plate 284, Plate 285, Plate 286, Plate 287, and Plate 288). During the summer of 2009, dissolved oxygen conditions in Lake Francis Case varied longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. A significant area of low dissolved oxygen (i.e., <5 mg/l) occurred in the downstream area of the reservoir near the dam (Plate 286). The area of low dissolved oxygen occurred along the reservoir bottom in the hypolimnion, and dissipated in late-August and September when thermal stratification broke down and reservoir mixing occurred.

5.6.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Dissolved oxygen depth-profiles measured during the summer at site FTRLK0880A over the 5-year period 2005 through 2009 were plotted (Plate 289). Dissolved oxygen levels exhibited occasional gradients with depth. On six occasions (i.e., July 2006, July 2007, July 2009, August 2005, August 2007, and August 2008), hypolimnetic dissolved concentrations fell below 5.0 mg/l. Dissolved oxygen levels below 5 mg/l occurred near the reservoir bottom from mid-July through August, when thermal stratification was maintained in Lake Francis Case.

5.6.2.1.4 Water Clarity

5.6.2.1.4.1 Secchi Transparency

Figure 5-15 displays a box plot of the Secchi depth transparencies measured along Lake Francis Case at five sites FTRLK0880, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW (RM968), and Big Bend Dam tailwaters during the 4-year period 2006 through 2009. The Secchi depth of the Big Bend Dam tailwaters was taken to be the Secchi depth measured in Lake Sharpe at the near-dam monitoring site (i.e., BBDLK0987A). The inflow of the White River to Lake Francis Case is between monitoring sites FTRLK0940DW and FTRLK0968DW at RM956. Secchi depth transparency significantly decreased from the Big Bend Dam tailwaters to the upstream reaches of Lake Francis Case (Figure 5-15). The lower transparencies in the upstream reaches of the reservoir are attributed to the shallowness of the reservoir in this area and the resuspension of deposited bottom sediments with wind and wave action. Water transparency generally increased in a downstream direction from the upstream reaches of the reservoir to near the dam (Figure 5-15). However, the inflow of the White River seemingly maintained reduced the transparencies in the upstream reaches of the reservoir. The near-surface transparency of Lake Francis Case measured near the dam was significantly higher than the transparency measured in upstream reaches of the reservoir (Figure 5-15).

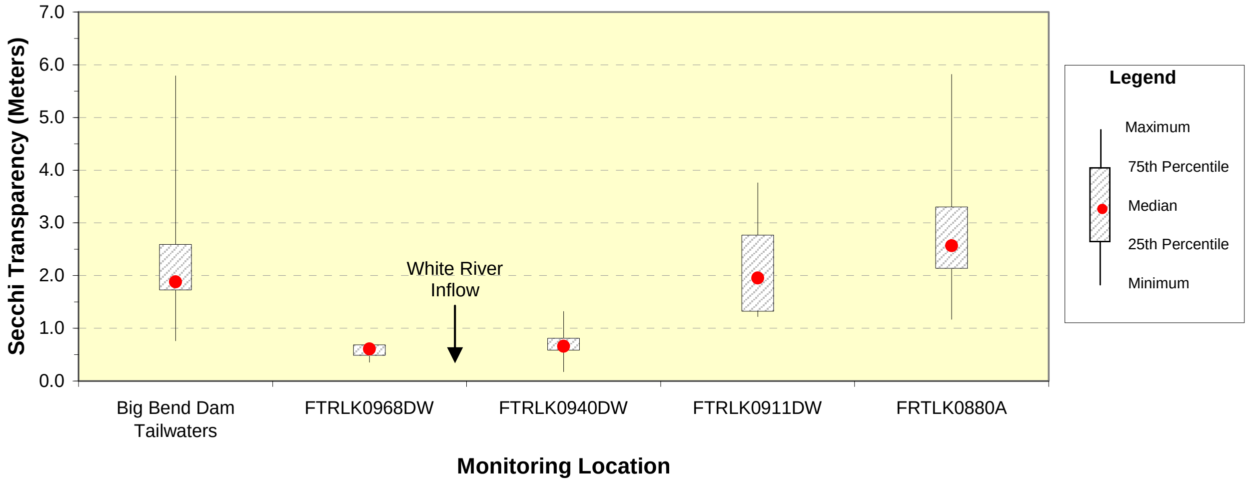

Figure 5-15. Box plot of Secchi transparencies measured along Lake Francis Case during the 4-year period 2006 through 2009. (Note: monitoring sites are oriented on the x-axis in an upstream to downstream direction.)

5.6.2.1.4.2 Turbidity

Monthly (i.e., May, June, July, August, and September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites FRTLK0880A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW and BBDPP1 during 2009 (Plate 290, Plate 291, Plate 292, Plate 293, and Plate 294). As seen in the contour plots, turbidity levels monitored in Lake Francis Case during 2009 showed little longitudinal and vertical variation. This is markedly different from the turbidity conditions monitored in 2008 (see 2008 Report – Water Quality Conditions in the Missouri River Mainstem System, USACE 2009c). In 2008, the inflow of the White River significantly increased the turbidity of Lake Francis Case in the upper reaches of the reservoir. Elevated levels of turbidity attributable to the inflow of the White River were regularly seen in Fort Randall Reservoir up to 25 miles downstream from the White River inflow.

5.6.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Lake Francis Case during the summer were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 1-meter of the reservoir bottom. The compared samples were collected at the near-dam site FTPLK0880A during the 5-year period 2005 through 2009. During the period a total of 20 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 295). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for water temperature, dissolved oxygen, ORP, and pH. Parameters that were significantly lower in the near-bottom water of Lake Francis Case included: water temperature ($p < 0.001$), dissolved oxygen ($p < 0.001$), and pH ($p < 0.001$). Parameters that were significantly higher in the near-bottom water included: ORP ($p < 0.001$).

5.6.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Lake Francis Case were calculated from monitoring data collected at sites FTRLK0880A, FTRLK0911DW, FTRLK0940DW, and FTRLK0968DW during the 4-year period 2006 through 2009 (Table 5-20). The calculated TSI values indicate that the lacustrine zone of the reservoir near the dam (site FTRLK0880A) is mesotrophic, the area near site FTRLK0911DW is moderately eutrophic, and the upstream transition and riverine zones of the reservoir (sites FTRLK940DW and FTRLK0968DWDW) are eutrophic.

Table 5-20. Mean Trophic State Index (TSI) values calculated for Lake Francis Case. TSI values are based on monitoring at the identified four sites during the 4-year period 2006 through 2009.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
FTRLK0880A	46	52	49	49
FTRLK0911DW	50	49	54	51
FTRLK0940DW	66	52	58	59
FTRLK0968DW	68	55	59	60

Note: See Section 4.1.4 for discussion of TSI calculation.

5.6.2.1.7 Phytoplankton Community

Phytoplankton grab samples collected from Lake Francis Case at sites FTRLK0880A, FTRLK0911DW, FTRLK0940DW, and FTRLK0968DW during the spring and summer of the 5-year period 2005 through 2009 are summarized in Plate 296, Plate 297, Plate 298, and Plate 299. The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The general prevalence of these taxonomic divisions in the reservoir, based on taxa occurrence, were Bacillariophyta > Chlorophyta > Cryptophyta/Cyanobacteria/Pyrrophyta > Chrysophyta/ Euglenophyta. The diatoms were generally the most abundant algae based on percent composition (Plates 296 - 299). The Shannon-Weaver genera diversity indices calculated for the 74 phytoplankton samples collected at the four sites ranged from 0.27 to 2.71 and averaged 1.43 at site FTRLK0880A, 1.57 at site FTRLK0911DW, 1.66 at site FTRLK0940DW, and 1.55 at site FTRLK0968DW. Dominant phytoplankton genera sampled at the five sites in 2009 (i.e., genera comprising more than 10% of the total biovolume of at least one sample collected in 2009) included the Bacillariophyta: *Asterionella*, *Aulacoseira*, *Fragilaria,* and *Stephanodiscus*; Chlorophyta: *Pyramimonas*; Chrysophyta: *Dinobryon* and *Mallomonas*; Cryptophyta: *Cryptomonas* and *Rhodomonas*; Cyanobacteria: *Anabaenopsis* and *Aphanizomenon;* and Pyrrophyta: *Ceratium*. The highest concentration of the Cyanobacteria microcystin toxin measured at the four sites during the 5-year-period 2005 through 2009 was 1.8 ug/l at site FTRLK0880A (Plate 271).

5.6.2.1.8 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota’s impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored in Lake Francis Case during the 5-year period 2005 through 2009 did not indicate impairment of any designated water quality beneficial uses.

5.6.2.2 Water Quality Trends (1980 through 2009)

Water quality trends over the 30-period of 1980 through 2009 were determined for Lake Francis Case for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam, ambient monitoring site (i.e., site FTRLK0880A). Plate 300 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., α = 0.05). For the assessment period, Lake Francis Case exhibited a significant decreasing trend for Secchi depth (Plate 300). No significant trends were detected for total phosphorus, chlorophyll *a* and TSI (Plate 300). Over the 30-year period, the downstream reach of Lake Francis Case has generally remained in a mesotrophic state (Plate 300).

5.6.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI RIVER INFLOW TO LAKE FRANCIS CASE

5.6.3.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions of the Missouri River inflow to Lake Francis Case is taken to be the monitored water quality conditions of the outflow from Big Bend Dam. See Plate 244 and Plate 245 for a summary of the water quality conditions monitored on the water discharged through Big Bend Dam.

5.6.3.2 Missouri River Inflow Nutrient Flux Conditions

Nutrient flux rates for the Missouri River inflow to Lake Francis Case over the last 5 years were calculated based on water quality conditions monitored on water discharged through Big Bend Dam (i.e. site BBDPP1). See Table 5-18 for the nutrient flux rates calculated for the monitored Big Bend Dam discharges.

5.6.3.3 Mean Daily Discharge and Temperature

Mean daily discharge and water temperature of the Big Bend Dam outflow were determined for 2005, 2006, 2007, 2008, and 2009. These are considered the water quality conditions of the Missouri River inflow to Lake Francis Case. Plate 301, Plate 302, Plate 303, Plate 304, and Plate 305, respectively, plot 2005, 2006, 2007, 2008, and 2009 mean daily water temperature and flow for the Big Bend Dam discharge.

5.6.4 WATER QUALITY AT THE FORT RANDALL POWERPLANT

5.6.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 306 and Plate 307 summarize the water quality conditions that were monitored on water discharged through Fort Randall Dam during the 5-year period 2005 through 2009. A review of these results indicated no major water quality concerns.

5.6.4.2 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota's impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored in Fort Randall Dam discharge during the 5-year period 2005 through 2009 did not indicate impairment of any designated water quality beneficial uses of the downstream Missouri River.

5.6.4.3 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time series plots for temperature and dam discharge monitored at the Fort Randall powerplant during the 5-year period of 2005 through 2009 were constructed (Plate 308 - Plate 317). Monitored water temperatures showed seasonal cooling and warming through each calendar year. Daily water temperatures remained fairly stable during the winter, early spring, and fall and exhibited considerable variability during the late spring and summer. When thermal stratification becomes established in Lake Francis Case during the late spring, the temperature of the water discharged through the dam becomes highly dependent upon the discharge rate of the dam. This indicates that the vertical extent of the withdrawal zone in the reservoir is dependent upon the discharge rate of the dam. This is believed to be a result of the design of the intake structure (i.e., bottom withdrawal) and the presence of the submerged approach channel leading to the intake structure. Water is likely drawn from an extended vertical zone in Lake Francis Case year-round, but is only evident in the temperatures monitored at the powerhouse during reservoir thermal stratification during the summer. When thermal stratification breaks down in the summer, the high correlation between dam discharge and the temperature of the discharged water no longer occurs. This occurred on September 1, 2005 (Plate 309), late-July in 2006 (Plate 311), September 1, 2007 (Plate 313), September 1, 2008 (Plate 315), and mid-August 2009 (Plate 317).

Semiannual time series plots for dissolved oxygen and dam discharge monitored at the Fort Randall powerplant during the 5-year period of 2005 through 2009 were also constructed (Plate 318 - Plate 326). (Note: *Due to equipment failure, no dissolved oxygen measurements were recorded in 2008 after early June.)* Dissolved oxygen levels remained relatively high and stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall. The lowest dissolved oxygen levels occurred during mid-summer. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. The decreasing dissolved oxygen in the summer is attributed to ongoing degradation of dissolved oxygen in the lower hypolimnion as the summer progressed. Water is withdrawn from Lake Francis Case into the dam's power tunnels approximately 2 feet above the reservoir bottom. During the summer when Lake Francis Case is thermally stratified, dissolved oxygen levels degrade near the reservoir bottom. Under such conditions, low dam discharge rates pull water with low dissolved oxygen concentrations from the near-bottom region of the hypolimnion.

During the 6-year period 2004 through 2007 and 2009, 2,982 hourly measurements of dissolved oxygen were recorded in August. Of these measurements, 546 (18%) were less than the 5 mg/l dissolved oxygen water quality standard for the protection of Warmwater Permanent Fish Life Propagation. The low dissolved oxygen measurements were associated with low- or no-flow discharge conditions. The no-flow conditions may be measurements of "static water" in the penstocks that is not being continuously discharged. This water is believed to have been drawn into the penstocks along the reservoir bottom as power generation was ramped down. The lowest dissolved oxygen concentration recorded was 2.0 mg/l on August 25 and 26, 2007. Seemingly, the low dissolved oxygen levels are related to oxygen degradation in the hypolimnion during late summer. During periods of lower discharge, water is drawn along the bottom of the submerged approach channel to the dam's intake tower. This is where low dissolved oxygen would occur in the hypolimnion during mid- to late summer. A potential concern that will be investigated in the future is whether the low dissolved oxygen levels monitored in the powerplant are reflective of dissolved oxygen levels occurring in the tailwaters immediately downstream of the Fort Randall Dam.

5.6.4.4 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Lake Francis Case

Plate 327, Plate 328, Plate 329, Plate 330, and Plate 331, respectively, plot the mean daily water temperatures monitored for the Missouri River at Big Bend (site BBDPP1) and the Fort Randall powerplants (site FTRPP1) for 2005, 2006, 2007, 2008, and 2009. Inflow temperatures of the Missouri River to Lake Francis Case tend to be at little warmer than the outflow temperatures of Fort Randall Dam during the spring and early summer. Outflow temperatures of the Fort Randall Dam discharge tend to be a little warmer than the Missouri River inflow temperatures in the late-summer and fall.

5.6.4.5 Nutrient Flux Conditions of the Fort Randall Dam Discharge to the Missouri River

Nutrient flux rates for the Fort Randall Dam discharge to the Missouri River over the 5-year period 2005 through 2009 were calculated based on samples taken from the Fort Randall powerplant (i.e. site FTRPP1) and the dam discharge at the time of sample collection (Table 5-21). The samples collected in the powerplant are taken from the raw water supply line and are believed to be unbiased regarding particulate-associated constituents. Therefore, the flux rates calculated for the Fort Randall Dam discharge give an unbiased estimate of the flux rates for all the constituents, including total phosphorus and total organic carbon. The maximum flux rates for all the constituents are believed to be attributed to higher dam discharges.

Table 5-21. Summary of nutrient flux rates (kg/sec) calculated for the Fort Randall Dam discharge to the Missouri River (i.e., site FTRPP1) during January through December over the 5-year period 2005 through 2009.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	51	51	51	51	51	37	49
Mean	19,548	0.0207	0.2204	0.0163	0.0137	0.0060	1.6878
Median	17,900	n.d.	0.1920	n.d.	0.0088	n.d.	1.5807
Minimum	0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	41,200	0.1551	1.0179	0.3810	0.1104	0.0448	4.3890

Note: Nondetectable values set to 0 for flux calculations.

5.6.5 WATER QUALITY IN THE MISSOURI RIVER DOWNSTREAM OF FORT RANDALL DAM

5.6.5.1 Missouri River Reach – Fort Randall Dam to Lewis and Clark Lake

The Missouri River downstream from Fort Randall Dam (RM880) flows in a southeasterly direction for approximately 44 miles in an unchannelized river to Lewis and Clark Lake. The major tributary in this reach is the Niobrara River which enters the Missouri River from Nebraska at RM843.5. In this reach, the Missouri River meanders in a wide channel with flow restricted to generally one main channel. Only a few side channels and backwaters are present, except at the lower end of the reach in the Lewis and Clark Lake delta. The 39-mile reach of the Missouri River from Fort Randall Dam to Running Water, SD has been designated a National Recreational River under the Federal Wild and Scenic Rivers Act (WSRA). The tailwater area of Fort Randall Dam, from RM880 to RM860, has experienced up to 6 feet of riverbed degradation and channel widening during the 1953 to 1997 time period. The rate of erosion has decreased over this period. Streambank erosion since closure of the dam in 1953 has

averaged about 35 acres per year. This compares to a pre-dam rate of 135 acres per year. The Missouri River has coarser bed material above RM870 than below, indicating some armoring of the channel immediately downstream of the dam. Downstream of the tailwater area, less erosion of the bed and streambank occurs.

5.6.5.1.1 National Recreation River Designation Pursuant to the Federal Wild and Scenic Rivers Act

The 39-mile "natural-channel" reach of the Missouri River from Fort Randall Dam to the headwaters of Lewis and Clark Lake has been designated as a National Recreational River under the Federal WSRA. The National Park Service (NPS) manages the 39-mile reach pursuant to the WSRA. The justification that supported that this reach of the Missouri River be protected as a recreational river identified its outstanding remarkable recreational, fish and wildlife, aesthetic, historical, and cultural values. Under the WSRA, the U.S. Department of Interior (i.e., NPS) is mandated to administer this reach in a manner that will protect and enhance these values for the benefit and enjoyment of present and future generations.

5.6.5.1.2 State Designations and Listings Pursuant to the Federal Clean Water Act

Pursuant to the Federal Clean Water Act (CWA), the States of South Dakota and Nebraska have designated water quality-dependent beneficial uses, in their State water quality standards, for the Missouri River from of Fort Randall Dam to Lewis and Clark Lake. South Dakota has designated the following uses for this reach of the Missouri River: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. Nebraska has designated the following uses to this reach of the Missouri River: primary contact recreation, Class I warmwater aquatic life, agricultural water supply, and aesthetics. It has designated the use of drinking water supply to the river below the confluence of the Niobrara River. Nebraska has also designated the reach between the Nebraska-South Dakota border and Lewis and Clark Lake an Outstanding State Resource Water for "Tier 3" protection under the water quality standard's antidegradation policy. Neither of the States has placed this reach of the Missouri River on their Section 303(d) list of impaired waters, nor has issued a fish consumption advisory for this reach of the Missouri River.

The national interpretation with respect to the Outstanding National Resource Waters protected under "Tier 3" of the antidegradation policy is that no new or increased discharges are allowed. The only exception to this is that States (i.e., Nebraska) may allow some limited activities which result in temporary and short-term changes in water quality.

5.6.5.2 <u>Monitored Water Quality Conditions</u>

The District, in cooperation with the Nebraska Department of Environmental Quality, conducted fixed-station water quality monitoring at two sites along the Missouri River from Fort Randall Dam to Lewis and Clark Lake. The locations of the two sites were Fort Randall Dam tailwaters (site FTRRRTW1) and the Missouri River near Verdel, NE (site MORRR0851) (see Figure 5-17). During the 5-year period of 2005 through 2009, water quality samples were collected monthly from October through March and monthly to biweekly from April through September. Plate 332 and Plate 333 summarize the water quality conditions that were monitored at the two sites. A review of these results indicated no major water quality concerns.

5.7 GAVINS POINT

5.7.1 BACKGROUND INFORMATION

5.7.1.1 Project Overview

Gavins Point Dam is located on the Missouri River at RM 811.1 on the South Dakota-Nebraska border in southeast South Dakota and northeast Nebraska, 4 miles west of Yankton, SD. The closing of Gavins Point Dam in 1955 resulted in the formation of Gavins Point Reservoir (Lewis and Clark Lake). The reservoir is 25 miles long, covers 31,000 acres, and has 90 miles of shoreline when full. Table 5-22 summarizes how the surface area, volume, mean depth, and retention time of Lewis and Clark Lake vary with pool elevations. Lewis and Clark Lake is normally regulated near 1206.0 ft-msl in the spring and early summer with variations day to day due to rainfall runoff. The reservoir level is then increased to elevation 1207.5 ft-msl following the least tern and piping plover nesting season for reservoir recreation enhancement. Major inflows to Lewis and Clark Lake are the Missouri River and Niobrara River. Water discharged through Gavins Point Dam for power production is withdrawn from the bottom of Lewis and Clark Lake at an invert elevation of 1139.5 ft-msl. Figure 5-16 shows a schematic drawing of the powerplant intake structure at Gavins Point Dam.

Table 5-22. Surface area, volume, mean depth, and retention time of Lewis and Clark Lake at different pool elevations based on 2007 survey.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1210	29,956	450,070	15.0	0.02305
1205	23,029	318,732	13.8	0.01632
1200	18,819	215,126	11.4	0.01102
1195	14,278	132,308	9.3	0.00677
1190	9,921	71,711	7.2	0.00367
1185	5,202	35,027	6.7	0.00179
1180	3,393	14,543	4.3	0.00074
1175	1,067	3,855	3.6	0.00020
1170	371	728	2.0	0.00004

Average Annual Inflow (1967 through 2009) = 19.62 Million Acre-Feet.
Average Annual Outflow: (1967 through 2009) = 19.53 Million Acre-Feet.
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1210-1208 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 1208-1204.5 ft-msl), Carryover Multiple Use Zone (none), and Permanent Pool Zone (elev. 1204.5-1160 ft-msl). All elevations are in the NGVD 29 datum.

Gavins Point was authorized for the proposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Over the period 1967 through 2009, the three generating units at Gavins Point Dam have produced an annual average 0.727 million mega-watt hours (MWh) of electricity, which has a current revenue value of approximately $12 million. The recent drought in the western United States curtailed releases and power production at the Mainstem System projects, including Gavins Point. Power production at the Gavins Point Dam generating units averaged an annual 0.567 MWh over the 5-year period 2005 through 2009. Habitat for two endangered species, pallid sturgeon and interior least tern, and one threatened species, piping plover, occur within the project area. Lewis and Clark Lake is a source water supply (drinking water) for Springfield, SD (RM832) , Cedar Knox Rural Water District (RM823 – Crofton, Fordice, St. Helena, and Obert, NE), and Bon Homme-Yankton Rural Water District (RM818 – 15 communities). Gavins Point is an important recreational resource and a major visitor destination in South Dakota and Nebraska.

Figure 5-16. Diagrammatic drawing of powerplant intake structure at Gavins Point Dam.

5.7.1.2 Water Quality Standards Classifications and Section 303(d) Listings

5.7.1.2.1 Lewis and Clark Lake

Pursuant to the Federal Clean Water Act, the State of South Dakota has designated the following water quality-dependent beneficial uses for Lewis and Clark Lake: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of Nebraska has designated the following beneficial uses to Lewis and Clark Lake: primary contact recreation, Class I warmwater aquatic life, drinking water supply, agricultural water supply, industrial water supply, and aesthetics. The uses designated by the States of South Dakota and Nebraska to Lewis and Clark Lake are consistent with each other. Neither of the two States has placed Lewis and Clark Lake on the State's Section 303(d) list of impaired waters, or has issued fish consumption advisories for the reservoir.

5.7.1.2.2 Missouri River Downstream of Gavins Point Dam

See Section 6 for a discussion of the Lower Missouri River downstream of Gavins Point Dam.

5.7.1.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at the Gavins Point Project since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow to and outflow from the reservoir. A 3-year intensive water quality survey scheduled for 2008 through 2010 is currently underway at the Gavins Point Project. An investigative study to evaluate the water quality impacts of constructing emergent sandbar habitat (ESH) in the headwaters of Lewis and Clark Lake was conducted in 2008 and the findings of that study are available in the separate report, "Creation of Emergent Sandbar Habitat (ESH) in the Headwaters of Lewis and Clark Lake and the Impacts on Water Quality" (USACE, 2009d). Figure 5-17 shows the location of sites at the Gavins Point Project that have been monitored by the District for water quality during the 5-year period 2005 through 2009. The near-dam location (i.e., site GPTLK0811A) has been continuously monitored since 1980.

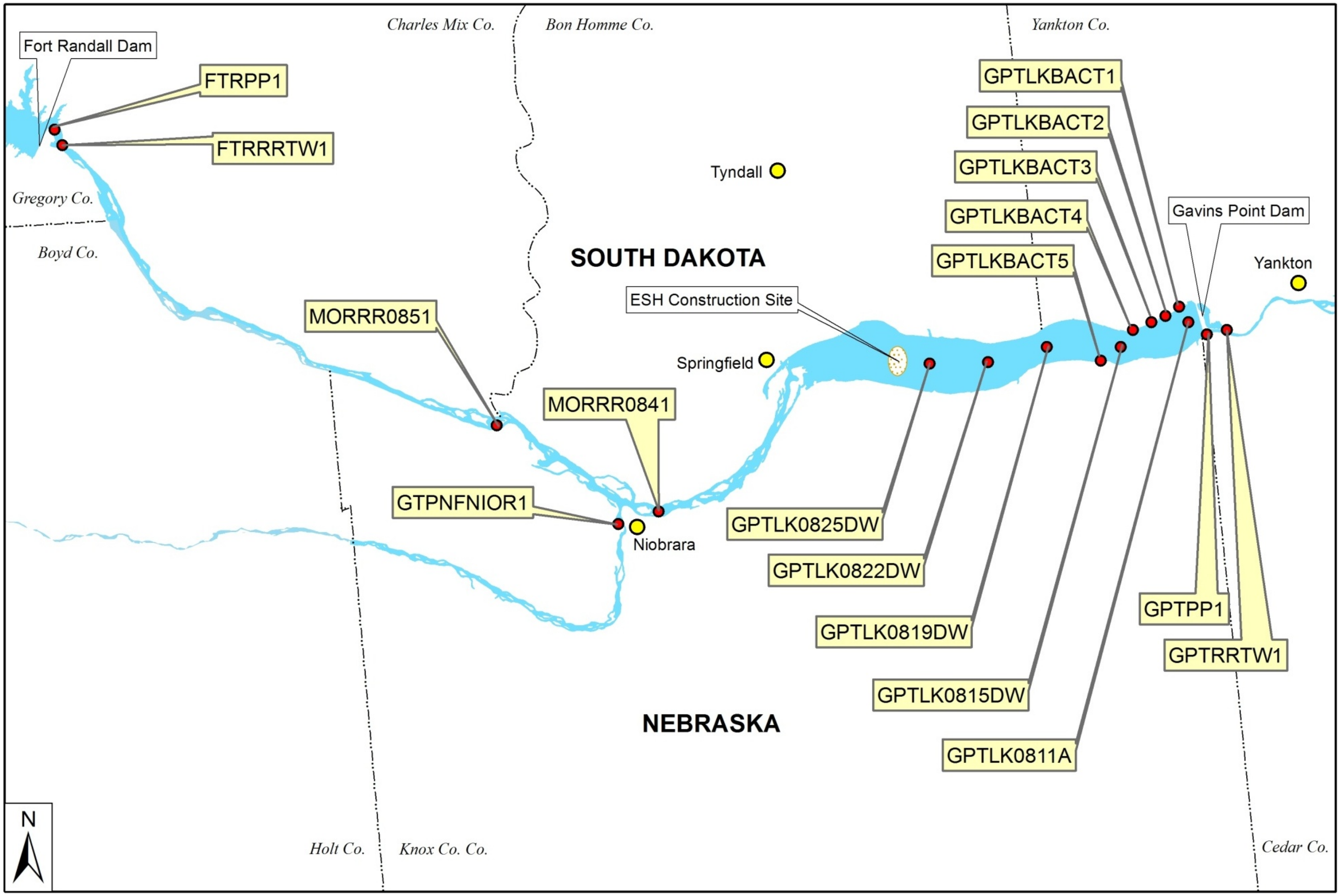

Figure 5-17. Location of sites where water quality monitoring was conducted by the District at the Gavins Point Project during the period 2005 through 2009.

5.7.2 WATER QUALITY IN LEWIS AND CLARK LAKE

5.7.2.1 <u>Existing Water Quality Conditions</u>

5.7.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Lewis and Clark Lake at sites GTPLK0811A, GTPLK0815DW, GTPLK0819DW, GTPLK0822DW, and GTPLK0825DW from May through September during the 5-year period 2005 through 2009 are summarized in Plate 334, Plate 335, Plate 336, Plate 337, and Plate 338. A review of these results indicated possible water quality concerns regarding dissolved oxygen, nutrients (i.e., total nitrogen and phosphorus), and chlorophyll *a*. Based on the criteria for the protection of warmwater aquatic life, 9 percent of the dissolved oxygen measurements taken at the monitoring site near Gavins Point Dam (i.e., GPTLK0811A) did not meet the dissolved oxygen criterion of 5 mg/l. All but one of the dissolved oxygen measurements less than the criterion occurred in a defined hypolimnetic zone where 63 percent dissolved oxygen measurements were less than 5 mg/l. The Nebraska nutrient criteria for chlorophyll *a*, total nitrogen, and total phosphorus applicable to Lewis and Clark Lake, a classified R9 reservoir, were regularly exceeded throughout the reservoir.

5.7.2.1.2 Summer Thermal Stratification

5.7.2.1.2.1 Monthly Longitudinal Temperature Contour Plots

Summer thermal stratification of Lewis and Clark Lake during 2009 is described by the monthly longitudinal temperature contour plots based on depth-profile temperature measurements taken in June, July, August, and September (Plate 339, Plate 340, Plate 341, and Plate 342. The contour plots were constructed along the length of the reservoir. As seen in the contour plots, water temperature in Lewis and Clark Lake varies longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Although some summer thermal stratification of Lewis and Clark Lake can occur, the relative shallowness, short retention time, and bottom withdrawal of the reservoir seemingly inhibit the formation of a strong thermocline and long-lasting stratification during the summer.

5.7.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Lewis and Clark Lake at the deep water area near the dam is described by the depth-profile temperature plots measured over the 5-year period 2005 through 2009. Depth-profile temperature plots measured during the summer months were compiled (Plate 343). Minor temperature-depth gradients occasionally occur in Lewis and Clark Lake in the near-dam area during the summer (Plate 343).

5.7.2.1.3 Summer Dissolved Oxygen Conditions

5.7.2.1.3.1 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen longitudinal contour plots were constructed along the length of Lewis and Clark Lake based on depth-profile measurements taken in June, July, August, and September of 2009 (Plate 344, Plate 345, Plate 346, and Plate 347). During the summer of 2009, dissolved oxygen conditions in Lewis and Clark Lake varied longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Dissolved oxygen levels below 5 mg/l first appeared at the reservoir bottom near the dam in July (Plate 345). Somewhat degraded dissolved oxygen levels remained near the reservoir bottom in the near-dam area during August and September (Plate 346 and Plate 347). There appears to have been enough thermal stratification in Lewis and Clark Lake during the summer of 2009 to allow for the degradation of dissolved oxygen levels in a small area near the dam.

5.7.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Lewis and Clark Lake at the deep-water area near the dam are described by the depth-profile dissolved oxygen plots measured over the 5-year period 2005 through 2009. Depth-profile dissolved oxygen plots measured during the summer months at site GPTLK0811A were compiled (Plate 348). Dissolved oxygen levels below 5 mg/l regularly occurred near the bottom of the reservoir, and levels near the reservoir bottom were less than 2 mg/l on two occasions.

5.7.2.1.4 Water Clarity

5.7.2.1.4.1 Secchi Transparency

Figure 5-18 displays a box plot of the Secchi depth transparencies measured along Lewis and Clark Lake at the five sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW during 2008 and 2009. Secchi depth transparency increased in a downstream direction from the upper reaches of the reservoir to near the dam (Figure 5-18). This is attributed to suspended sediment in the inflowing Niobrara and Missouri Rivers settling out in the reservoir as current velocities slow. The surface waters near Gavins Point Dam are significantly clearer than the upstream regions of the reservoir.

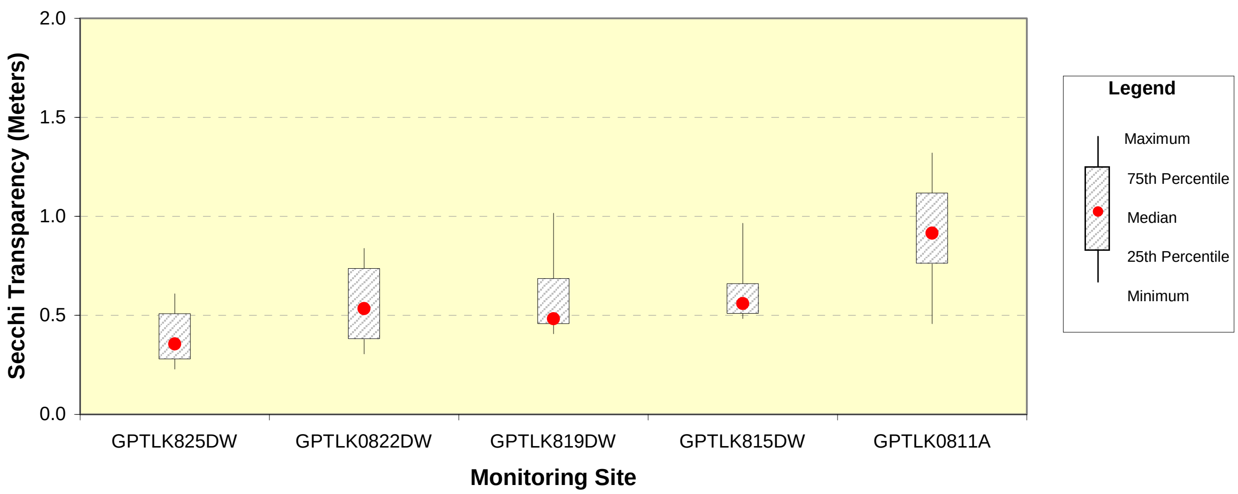

Figure 5-18. Box plot of Secchi transparencies measured in Lewis and Clark Lake during 2008 and 2009.

5.7.2.1.4.2 Turbidity

Monthly (i.e., June, July, August, and September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW during 2009 (Plate 349, Plate 350, Plate 351, and Plate 352). As seen in the contour plots, turbidity levels measured in Lewis and Clark Lake during 2009 varied longitudinally from the dam to the reservoir's upstream reaches; especially in June. This is attributed to the turbid conditions of the inflowing Missouri River which is impacted by the inflow of the Niobrara River 16 miles upstream of Lewis and Clark Lake.

5.7.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Lewis and Clark Lake during the summer were compared. Near-surface conditions were represented by samples collected

within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 1-meter of the reservoir bottom. The compared samples were collected at the near-dam site GPTLK0811A during the 5-year period 2005 through 2009. During the period a total of 20 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 353). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for water temperature, dissolved oxygen, ORP, pH, and total ammonia. Parameters that were significantly lower in the near-bottom water of Lewis and Clark Lake included: water temperature ($p < 0.001$), dissolved oxygen ($p < 0.001$), and pH ($p < 0.001$). Parameters that were significantly higher in the near-bottom water included: ORP ($p < 0.001$) and total ammonia ($p < 0.05$).

5.7.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Lewis and Clark Lake were calculated from monitoring data collected during the 2008 and 2009 (Table 5-23). The calculated TSI values indicate that the area near the dam (i.e., site GPTLK0811A) is eutrophic, the middle and upper reaches of the reservoir (i.e., sites GPTLK0819DW and GTPLK0825DW) are eutrophic to hypereutrophic.

Table 5-23. Mean Trophic State Index (TSI) values calculated for Lewis and Clark Lake. TSI values are based on monitoring at the identified three sites during 2008 and 2009.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
GPTLK0811A	59	52	66	59
GPTLK0819DW	68	57	70	65
GPTLK0825DW	75	57	70	67

Note: See Section 4.1.4 for discussion of TSI calculation.

5.7.2.1.7 Phytoplankton Community

Phytoplankton grab samples collected from Lewis and Clark Lake at sites GPTLK0811A, GPTLK0819DW, and GPTLK0825DW during the spring and summer of the 5-year period 2005 through 2009 are summarized in Plate 354, Plate 355, and Plate 356. The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The general prevalence of these taxonomic divisions in the reservoir, based on taxa occurrence, were Bacillariophyta > Chlorophyta > Cryptophyta/Pyrrophyta/Cyanobacteria > Euglenophyta/Chrysophyta. The diatoms were generally the most abundant algae based on percent composition. The Shannon-Weaver genera diversity indices calculated for the 43 phytoplankton samples collected at the three sites ranged from 1.04 to 2.84 and averaged 1.68 at site GPTLK0811A, 1.87 at site GPTLK0819DW, and 2.29 at site GPTLK0825DW. Dominant phytoplankton genera sampled at the three sites in 2009 (i.e., genera comprising more than 10% of the total biovolume of at least one sample collected in 2009) included the Bacillariophyta *Asterionella*, *Cyclotella, Fragilaria, Nitzschia, and Stephanodiscus*; Chlorophyta Pediastrum; Chrysophyta *Dinobryon;* Cryptophyta *Rhodomonas*, and Pyrrophyta *Ceratium*. The Cyanobacteria microcystin toxin was detected at a level of 14 ug/l at site GPTLK0811A in 2008 (Plate 334).

5.7.2.1.8 Bacteria Monitoring at Swimming Beaches on Lewis and Clark Lake

During the 5-year period 2005 through 2009, bacteria samples were collected weekly from May through September at five swimming beaches located on Lewis and Clark Lake. The five swimming beaches where the bacteria samples were collected were: Weigand Recreation Area (site GPTLKBACT5), Gavins Point Recreation Area (site GPTLKBACT4), Lewis and Clark Recreation Area – Midway West Beach (site GPTLKBACT3) and Midway East Beach (GPTLKBACT2), and the Marina Sailing Boat Area (site GPTLKBACT1) (Figure 5-17). Table 5-24 summarizes the results of the bacteria sampling. The geometric means were calculated as running geometric means for five consecutive weekly bacteria samples and nondetects were set to 1. The bacteria sampling results were compared to following bacteria criteria for support of "full-body contact" recreation:

Fecal Coliform:
Bacteria of the fecal coliform group should not exceed a geometric mean of 200/100ml, nor equal or exceed 400/100ml, in more than 10% of the samples. These criteria are based on a minimum of five samples taken within a 30-day period.

E. coli:
E. coli bacteria should not exceed a geometric mean of 126/100ml. For increased confidence of the criteria, the geometric mean should be based on a minimum of five samples taken within a 30-day period. Single sample maximum allowable density for designated bathing beaches is 235/100ml.

Based on these criteria and Nebraska's impairment assessment methodology (Section 4.1.6.2), "full-body contact" recreation was fully supported at the five sampled swimming beaches on Lewis and Clark Lake during the May through September recreational season during the 5-year period 2005 through 2009. It is noted that 7 percent of calculated geomeans at site GPTLKBACT5 (Weigand Recreation Area) exceeded the geometric mean criteria (Table 5-24).

5.7.2.1.9 Impairment of Designated Water Quality Beneficial Uses

Based on the State of Nebraska's impairment assessment methodology (Section 4.1.6.2), the water quality conditions monitored in Lewis and Clark Lake (i.e., chlorophyll *a*, total nitrogen, and total phosphorus) during the 5-year period 2005 through 2009 indicate impairment of aesthetics due to nutrients (Plate 334, Plate 335, Plate 336, Plate 337, and Plate 338). It is also noted that the estimated loss of 23.8 percent of the multi-purpose pool volume of Lewis and Clark Lake (Table 5-1) is approaching Nebraska's impairment identification criteria of 25 percent volume loss.

5.7.2.2 Water Quality Trends (1980 through 2009)

Water quality trends over the 30-year period of 1980 through 2009 were determined for Lewis and Clark Lake for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., site GPTLK0811A). Plate 357 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Lewis and Clark Lake exhibited significant trends for Secchi depth (decreasing) and TSI (increasing) (Plate 357). No significant trends were detected for total phosphorus and chlorophyll *a* (Plate 357). Over the 30-year period, the near-dam area of the reservoir has generally remained in a eutrophic state (Plate 357).

Table 5-24. Summary of weekly (May through September) bacteria sampling conducted at five swimming beaches on Lewis and Clark Lake over the 5-year period 2005 through 2009.

	Weigand Recreation Area (GPTLKBACT5)	Gavins Point Recreation Area (GPTLKBACT4)	Lewis & Clark Rec. Area Midway West (GPTLKBACT3)	Lewis & Clark Rec. Area Midway East (GPTLKBACT2)	Marina Sailing Boat Area (GPTLKBACT1)
Fecal Coliform Bacteria:					
Number of Samples	106	107	107	106	107
Mean	188	38	29	49	27
Median	21	12	8	8	6
Minimum	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	5,460	510	640	990	360
Percent of samples exceeding 400/100ml	8%	2%	1%	1%	0%
• **Geometric Mean**					
Number of Geomeans	87	87	87	87	87
Average	51	15	10	14	9
Median	25	12	8	9	7
Minimum	5	3	1	2	1
Maximum	682	66	69	67	39
Number of Geomeans exceeding 200/100ml	7%	0%	0%	0%	0%
***E. coli* Bacteria**					
Number of Samples	106	107	107	107	107
Mean	175	26	18	30	18
Median	15	10	6	4	4
Minimum	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	5,200	388	387	960	270
Percent of samples exceeding 235/100ml	13%	2%	1%	2%	1%
• **Geomean**					
Number of Geomeans	87	87	87	87	87
Average	43	11	7	8	6
Median	22	8	6	6	5
Minimum	3	2	n.d.	n.d.	2
Maximum	595	54	26	26	21
Number of Geomeans exceeding 126/100ml	7%	0%	0%	0%	0%

n.d. = Not detected.
Note: Not detected values set to 1 to calculate mean and geometric mean.

5.7.2.3 Creation of Emergent Sandbar Habitat (ESH) in the Headwaters of Lewis and Clark Lake and the Impacts on Water Quality

The U.S. Fish and Wildlife Service (USFWS) issued a Biological Opinion (BiOp) with recommendations for the U.S. Army Corps of Engineers' (Corps) operations of the Missouri River Mainstem System for protection and enhancement of threatened and endangered species. The BiOp found that the Corps' operations on the Missouri River were not likely to jeopardize the endangered

interior least tern *(Sterna antillarum)* and threatened piping plover *(Charadrius melodus)* populations if the Reasonable and Prudent Alternative (RPA) set forth in the BiOp was implemented. The RPA includes recommendations for the mechanical creation and maintenance of Emergent Sandbar Habitat (ESH) as nesting habitat for these two species in terms of habitat acres per river mile. In accordance with the BiOp, the Corps is conducting ongoing efforts to create and/or reclaim a sufficient amount of ESH to stabilize, and eventually recover, interior least tern and piping plover populations along the Missouri River. The Missouri River reach from Gavins Point Dam upstream to the confluence of the Niobrara River, which includes Lewis and Clark Lake, has been identified as a priority reach for both the interior least tern and piping plover. A project to create ESH in the upper reaches of Lewis and Clark Lake was implemented by the Corps during the period September 2006 to November 2008. Hydraulic dredging was used to construct two ESH complexes. The dredged material for building the sandbars was obtained from the "delta" of deposited material at the inflow of the Missouri River to Lewis and Clark Lake.

5.7.2.3.1 Use of Lewis and Clark Lake and the Gavins Point Dam Tailwaters as Source Water for Drinking Water

Lewis and Clark Lake is utilized for source water by two rural water districts that provide public drinking water; Cedar Knox Rural Water District (CKRWD) and the Bon Homme-Yankton Rural Water District (BYRWD). The City of Yankton draws source water for drinking water use from the Missouri River approximately 5 miles downstream of Gavins Point Dam.

5.7.2.3.2 Potential Impact of ESH Creation in Lewis and Clark Lake on the Occurrence of Trihalomethanes (THMs) in Treated Drinking Water Supplies

The following discussion is taken from the Water Quality Office Report, "Creation of Emergent Sandbar Habitat (ESH) in the Headwaters of Lewis and Clark Lake and the Impacts on Water Quality" (USACE, 2009d).

Pursuant to the Federal Safe Drinking Water Act, both rural water districts and the City of Yankton monitor their source and treated drinking water for compliance with federal drinking water standards. This monitoring includes testing for trihalomethanes (THMs) and quarterly reporting of the results to the appropriate State authorities. The current MCL (maximum contaminant level) for total THMs is 80 μg/l. When testing indicates the MCL for total THMs is exceeded, the water suppliers must notify their users, as well as increase the frequency of testing, numbers of tests, and data reporting. The water suppliers expressed concerns to the Corps that the creation of the ESH in Lewis and Clark Lake degraded water quality to the degree that it impacted the quality of their treated drinking water. Specifically, there was concern that the dredging and sandbar construction increased the level of organic matter (THM precursors) in the reservoir, and this lead to the water suppliers exceeding water quality standards in their treated drinking water for THMs.

THMs include the compounds trichloromethane (chloroform), bromodichloromethane, dibromochloromethane, and tribromomethane (bromoform). THMs are formed when free chlorine reacts with THM precursors, most of which occur naturally. THM formation in treated drinking water occurs when source water containing THM precursors is chlorinated during treatment. THMs do not occur naturally, only when the source water is treated with disinfectants such as chlorine. The organic matter that supplies the carbon compounds that serve as THM precursors in surface waters is derived from allochthonous and autochthonous material. Allochthonous organic matter in watersheds is leached from soils or decaying vegetation and transported to surface waters. Autochthonous organic matter is produced through algal, macrophyte, and bacterial production in surface waters.

THMs commonly occur in the treated drinking water provided by the CKRWD, BYRWD, and the City of Yankton. Quarterly THM levels historically reported by the three treatment facilities indicate a strong seasonal trend with lower levels occurring in the winter and higher levels in the spring and summer. Treatment processes and retention time in the distribution system seemingly have a significant impact on the THM levels occurring at the treatment facilities.

The historical data from BYRWD indicates THM levels are consistently less than half of the 80 μg/l THM MCL standard. The small range of values indicates the treated water is not prone to extreme THM values, and reflects an ability of the BYRWD to effectively manage their water treatment process given the quality of the source water. THM concentrations in the BYRWD treated water were very low before and after ESH construction, so any increase in THM precursor levels in Lewis and Clark Lake that may have occurred from ESH construction or other seasonal sources were manageable with no non-compliance occurrences observed in the quarterly data. The quarterly data indicate the ESH construction in the upper reaches of Lewis and Clark Lake did not have an appreciable impact on the THM levels measured in BYRWD's treated water.

The reported THM levels at Yankton are notably higher than the levels reported for BYRWD. The THM levels at Yankton indicate the treatment facility has a greater vulnerability to high THM values and a greater risk for THM non-compliance events. The treatment process may have a major impact on the occurrence of THMs and non-compliance events at Yankton. The occurrence of high THM levels in Yankton's treated water do not appear to be correlated with the dredging that occurred to construct the ESH in the upper reaches of Lewis and Clark Lake. The level of THM precursors present in the Missouri River at the Yankton water intake appear to rise with the increase in organic matter attributable to spring and summer runoff and algal production in Lewis and Clark Lake.

The reported THM levels at CKRWD were also notably higher than the levels reported for BYRWD. The THM levels at CYRWD also indicate the treatment facility has a greater vulnerability to high THM values and a greater risk for THM non-compliance events. The treatment process may also have a major impact on the occurrence of THMs and non-compliance events at CKRWD. It is not clear as to whether the ESH dredging in the upper reaches of Lewis and Clark Lake had a significant impact on the quarterly THM levels reported for CKRWD. THM levels reported in 2006 and 2007, when dredging occurred, do not indicate a noticeable impact as all quarterly results were within the historical range of normal seasonal variability. Quarterly reporting for 2008 indicated THM level greater than the historic maximum in the 4th quarter. This was during the period that dredging was completed on ESH complex 2.

Additional targeted water quality monitoring of treated water in the CKRWD distribution system during 2008 showed a strong seasonal trend in THM levels (i.e., low in early spring and early fall and high in the summer). THM levels in the CKRRWD distribution system were directly related to the distance from the treatment plant (i.e., locations the farthest away had the highest THM levels). Monitored THM levels associated with before and during ESH dredging periods did not indicate any impact; monitored THM levels were lower during ESH dredging.

Ambient water quality conditions monitored in Lewis and Clark Lake during 2008 were similar to conditions monitored in the past. Lewis and Clark Lake is in a eutrophic condition and experiences higher levels of algal growth during the summer. Targeted water quality monitoring was conducted in 2008 to evaluate the impact of the dredging to complete construction of ESH complex 2. Water quality monitoring of Lewis and Clark Lake was conducted immediately before and during dredging. The water quality monitoring included the parameter THM Formation Potential (THM-FP) which is a measure of the potential for THMs to form in water when under the influence of direct chlorination. Monitored levels of THM-FP (i.e., THM precursors) in Lewis and Clark Lake exhibited seasonality ("i.e., low levels in spring and fall and higher levels in the summer). This indicates that seasonal runoff and algal

production (lacustrine and riverine) may be a primary source of THM precursors in Lewis and Clark Lake. THM-FP levels measured in Lewis and Clark Lake were appreciably lower than levels measured in eutrophic reservoirs in New York and Kentucky (Bukaveckas et.al., 2007 and Stepczuk et.al., 1998). Monitoring conducted immediately before and during the dredging to complete ESH complex 2 did not detect any significant impact of the dredging on the water quality of Lewis and Clark Lake. Monitored levels of THM-FP in the reservoir were lower during ESH dredging when compared to levels monitored immediately before dredging.

5.7.2.3.3 Trihalomethane Precursors Monitored at the Inflow, Headwaters, and Outflow of Lewis and Clark Lake during 2009

When subject to chlorination during water treatment, THM precursors form trihalomethanes which are known carcinogens. Major precursors affecting THM formation in chlorinated drinking water are believed to be humic and fulvic substances and simple low-molecular-weight organic compounds. To evaluate this concern, THM Formation Potential (THM-FP), total organic carbon (TOC), chlorophyll *a*, and true color were measured in appropriate samples. THM-FP measures the amount of THMs that are formed in a sample that is chlorinated for an extended period. TOC and color give an indication of the presence of low-molecular-weight organic compounds. Color in water may result from the presence of natural metallic ions (iron and manganese), humus and peat materials, plankton, weeds, and industrial wastes. "True color" is the color of water from which turbidity has been removed. True color can be indicative of the amount of dissolved humic substances present in water, and dissolved humic substances can be THM precursors. Dissolved low-molecular weight organic matter is believed to form THMs more readily than "residual" organic matter.

THM-FP, TOC, chlorophyll *a*, and true color levels monitored at the Lewis and Clark Lake inflow (Missouri River at Niobrara, NE – site GPTNFMOR1), headwaters (Lewis and Clark Lake – site GPTLK0825DW), and outflow (Gavins Point Dam tailwaters – site GPTRRTW1) during 2009 were plotted. Figure 5-19 plots THM-FP, TOC, chlorophyll *a*, and true color levels monitored at the three sites. With the possible exception of chlorophyll *a*, the measured levels of the four parameters at the three sites were similar. Chlorophyll *a* levels were seemingly higher in the headwaters of Lewis and Clark Lake. The monitored levels of THM-FP, TOC, chlorophyll *a*, and true color in 2009 do not indicate that the construction of the Emergent Sandbar Habitat in the headwaters of Lewis and Clark Lake had a noticeable effect in raising THM precursor levels in the reservoir.

5.7.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI AND NIOBRARA RIVER INFLOWS TO LEWIS AND CLARK LAKE

5.7.3.1 Missouri River above the Confluence of the Niobrara River

5.7.3.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions of the Missouri River above the confluence of the Niobrara River are defined by the water quality conditions monitored in the outflow from Fort Randall Dam (site FTRPP1), in the Fort Randall Dam tailwaters (site FTRRRTW1), and in the Missouri River near Verdel, NE (site MORRR0851). Plate 306, Plate 307, Plate 332, and Plate 333 summarize water quality conditions monitored at these three sites over the 5-year period 2005 through 2009.

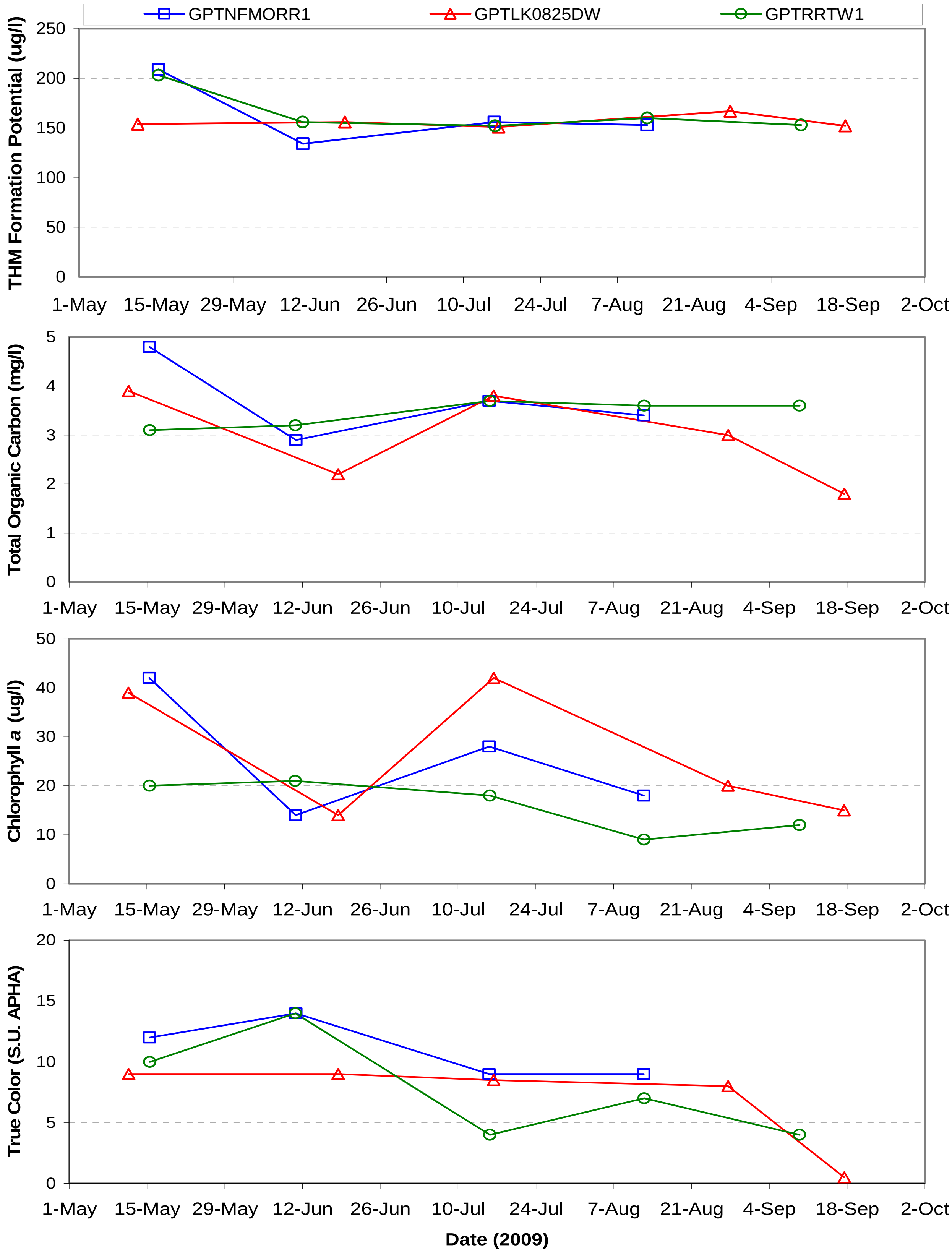

Figure 5-19. THM-FP, TOC, chlorophyll *a*, and true cooler levels measured at the inflow (GPTNFMORR1), headwaters (GPTLK0825DW), and outflow (GPTRRTW1) of Lewis and Clark Lake during 2009.

5.7.3.1.2 Nutrient Flux Conditions

The nutrient flux rates of the Missouri River above the confluence of the Niobrara River, over the 5-year period 2005 through 2009, were calculated based on near-surface water quality samples collected near Verdel, NE (i.e., site MORRR0851) and the instantaneous flow conditions at the time of sample collection (Table 5-25). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) are likely higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the flux rates given for total phosphorus and total organic carbon in Table 5-25 should be considered minimum estimates with the actual flux rates being higher. The maximum flux rates for all the constituents are believed to be attributed to higher flows during maximum power production at Fort Randall Dam.

Table 5-25. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Verdel, NE (i.e., site MORRR0851) over the 5-year period 2005 through 2009.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	71	71	71	71	71	11	69
Mean	21,759	0.0371	0.2925	0.0127	0.0241	0.0037	1.9686
Median	21,889	0.0202	0.2075	n.d.	0.0156	n.d.	1.8399
Minimum	3,012	n.d.	n.d.	n.d.	n.d.	n.d.	0.4245
Maximum	41,898	0.2527	1.2368	0.1543	0.2315	0.0128	5.1015

Note: Nondetectable values set to 0 for flux calculations.

5.7.3.1.3 Mean Daily Discharge and Temperature

Mean daily discharge and water temperature of the Fort Randall Dam outflow were determined for the 5-year period 2005 through 2009. These are considered the water quality conditions of the Missouri River above the confluence of the Niobrara River. Plate 358, Plate 359, Plate 360, Plate 361, and Plate 362 plot annual mean daily water temperature and flow for the Fort Randall Dam discharge for the 5-year period.

5.7.3.2 Niobrara River

5.7.3.2.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions that were monitored in the Niobrara River at site GPTNFNIOR1 (Figure 5-17) during 2008 and 2009 are summarized in Plate 363. A review of these results indicated no significant water quality concerns.

5.7.3.2.2 Nutrient Flux Conditions

Nutrient flux rates of the Niobrara River, near the river's confluence with the Missouri River, were calculated based on near-surface water quality samples collected near Niobrara, NE (i.e., site GPTNFNIOR1) and the instantaneous flow conditions at the time of sample collection (Table 5-26). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the

river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) are likely higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the flux rates given for total phosphorus and total organic carbon in Table 5-26 should be considered minimum estimates with the actual flux rates being higher. The maximum nutrient flux rates are attributed to greater nonpoint-source nutrient loadings associated with runoff conditions.

Table 5-26. Summary of nutrient flux rates (kg/sec) calculated for the Niobrara River near Verdel, NE (i.e., site GPTNFNIOR1) for 2008 and 2009.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	13	13	13	13	13	11	13
Mean	1,991	0.0027	0.0699	0.0466	0.0164	0.0019	0.2329
Median	1,710	0.0020	0.0552	0.0280	0.0112	0.0009	0.1846
Minimum	753	n.d.	0.0189	0.0009	0.0043	n.d.	0.0746
Maximum	3,560	0.0106	0.1988	0.1611	0.0511	0.0049	0.4728

Note: Non-detect values set to 0 for flux calculations.

5.7.3.2.3 Continuous Water Temperature Monitoring of the Niobrara River at USGS Gage Site 06465500 near Verdel, Nebraska

Through an agreement with the USGS, a water temperature monitoring probe was added to the USGS's gage (06465500) on the Niobrara River near Verdel, NE (i.e., near site GTPNFNIOR1). Beginning in April 2005, hourly water temperature measurements were recorded at the site. Plate 364, Plate 365, Plate 366, Plate 367, and Plate 368, respectively, plot mean daily water temperature and river discharge determined for 2005, 2006, 2007, 2008, and 2009.

5.7.3.3 Missouri River below the Confluence of the Niobrara River

5.7.3.3.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions that were monitored in the Missouri River near Niobrara, NE at site GPTNFMORR1 (Figure 5-17) during 2009 are summarized in Plate 369. A review of these results indicated no significant water quality concerns.

5.7.3.3.2 Nutrient Flux Conditions

Nutrient flux rates of the Missouri River downstream of the Niobrara River and upstream of Lewis and Clark Lake were calculated based on near-surface water quality samples collected from the Missouri River near Niobrara, NE (i.e., site GPTNFNIOR1) and the instantaneous flow conditions at the time of sample collection (Table 5-27). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) are likely higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the flux rates given for total phosphorus and total organic carbon in Table 5-27 should be considered minimum estimates with the actual flux rates being higher. The maximum nutrient flux rates are attributed to greater nonpoint-source nutrient loadings associated with runoff conditions.

Table 5-27. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Niobrara, NE (i.e., site GPTNFMORR1) for 2009.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	8	8	8	8	8	5	8
Mean	28,382	0.0339	0.6107	0.3920	0.0685	0.0172	2.4759
Median	27,046	0.0327	0.5148	0.2613	0.0661	0.0124	2.3144
Minimum	19,230	n.d.	0.1309	n.d.	n.d.	n.d.	1.6913
Maximum	41,857	0.0726	1.4104	1.1852	0.1541	0.0403	3.9707

Note: Non-detect values set to 0 for flux calculations.

5.7.3.3.3 Mean Daily Discharge and Temperature

The estimated mean daily discharge and temperature of the annual Missouri River inflow to Lewis and Clark Lake for 2005 through 2009 are plotted in Plate 370, Plate 371, Plate 372, Plate 373, and Plate 374. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, NE at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites.

5.7.4 WATER QUALITY AT THE GAVINS POINT POWERPLANT

5.7.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 375 and Plate 376 summarize the water quality conditions that were monitored on water discharged through Gavins Point Dam during the 5-year period 2005 through 2009. A review of these results indicated no major water quality concerns.

5.7.4.2 Impairment of Designated Water Quality Beneficial Uses

Based on the States of Nebraska and South Dakota impairment assessment methodologies (Sections 4.1.6.2 and 4.1.6.4), the water quality conditions monitored in Gavins Point Dam discharge during the 5-year period 2005 through 2009 did not indicate impairment of any designated water quality beneficial uses of the downstream Missouri River.

5.7.4.3 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time-series plots for temperature, dissolved oxygen, and dam discharge monitored at the Gavins Point powerplant during the 5-year period 2005 through 2009 were constructed. Water temperatures showed seasonal warming and cooling through each calendar year (Plate 377 - Plate 386). Dissolved oxygen levels remained relatively high and stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall (Plate 387 - Plate 396). Except for a few occasions in the spring, the lowest dissolved oxygen levels occurred during mid- to late July. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. The lower dissolved oxygen concentrations in July may be associated with degradation in the hypolimnion when limited thermal stratification is able to become established. There appeared to be little correlation between discharge rates and measured water temperature and dissolved oxygen concentrations.

5.7.4.4 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Lewis and Clark Lake

Plate 397, Plate 398, Plate 399, Plate 400, and Plate 401 annually plot the mean daily water temperatures estimated for the Missouri River inflow to Lewis and Clark Lake and monitored at the Gavins Point Dam powerplant (site GTPPP1) for the 5-year period 2005 through 2009. Inflow temperatures of the Missouri River to Lewis and Clark Lake tend to be at little cooler than the outflow temperatures of Gavins Point Dam during the spring to mid-summer. Outflow temperatures of the Gavins Point Dam discharge tend to be a little cooler than the Missouri River inflow temperatures in the late-summer and fall.

5.7.4.5 Nutrient Flux Conditions of the Gavins Point Dam Discharge to the Missouri River

Nutrient flux rates for the Gavins Point Dam discharge to the Missouri River over the 5-year period 2005 through 2009 were calculated based on samples taken from the Gavins Point powerplant (i.e. site GPTPP1) and the dam discharge at the time of sample collection (Table 5-28). The samples collected in the powerplant are taken from the raw water supply line and are believed to be unbiased regarding particulate-associated constituents. Therefore, the flux rates calculated for the Gavins Point Dam discharge give an unbiased estimate of the flux rates for all the constituents, including total phosphorus and total organic carbon. The maximum flux rates for all the constituents are believed to be attributed to higher dam discharges.

Table 5-28. Summary of nutrient flux rates (kg/sec) calculated for the Gavins Point Dam discharge to the Missouri River (i.e., site GTPPP1) during January through December over the 5-year period 2005 through 2009.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	50	50	50	50	50	38	49
Mean	17,218	0.0239	0.2751	0.0423	0.0305	0.0124	1.6211
Median	17,009	0.0116	0.2410	0.0232	0.0205	0.0085	1.5564
Minimum	8,000	n.d.	n.d.	n.d.	n.d.	n.d.	0.7136
Maximum	29,500	0.1620	0.9497	0.2414	0.1835	0.0866	3.5227

Note: Nondetectable values set to 0 for flux calculations.

5.8 COMPARISON OF EXISTING WATER QUALITY CONDITIONS AT THE MAINSTEM SYSTEM RESERVOIRS

During 5-year period of 2005 through 2009, conditions in the upper Missouri River basin were characterized by severe drought early in the period and more “normal” precipitation and runoff later in the period. During this period, Mainstem System reservoirs experienced historic low pool elevations and water in storage dropped to 46 percent of the Mainstem System storage capacity in February 2007. By the end of 2009 storage had recovered to 74 percent of the Mainstem System storage capacity. During the 5-year period reduced pool levels and reservoir volumes were especially pronounced at the upper three Mainstem System reservoirs: Fort Peck, Garrison, and Oahe. Drought induced reduction in reservoir volumes could reasonably be expected to have water quality ramifications due to reductions in the pollution assimilative capacity of the reservoirs and exposure of previously flooded sediments. The final impact of the existing drought on water quality conditions at the Mainstem System reservoirs is still to be

determined; however, monitoring of existing water quality conditions does not indicate major concerns other than the maintenance of coldwater fishery habitat in Lake Sakakawea during the drought-induced low reservoir pool elevations.

5.8.1 IMPAIRMENT OF DESIGNATED WATER QUALITY DEPENDENT BENEFICIAL USES

The attainment of water quality standards at the Mainstem System Projects, based on water quality conditions monitored over the 5-year period 2005 to 2009 by the District, is summarized in Table 5-29. Water quality standards attainment was defined as whether the designated beneficial uses in State water quality standards were impaired based on the monitored water quality conditions and defined State impairment assessment criteria. It is noted that the "official" determination of whether designated beneficial uses are impaired, pursuant to the Federal Clean Water Act, is made by the States pursuant to their Section 305(b) and Section 303(d) assessments (See Table 1-3). As shown in Table 1-3, the States of Montana and North Dakota currently list Fort Peck Lake and Lake Sakakawea, respectively, as impaired. The District defers to Montana's assessment of drinking water impairment, as the District does not monitor or review source water quality conditions of public drinking water facilities utilizing Fort Peck Lake as source water. The District's monitoring of Lake Sakakawea indicates a concern regarding the maintenance of coldwater habitat in the reservoir during low pool elevation.

Table 5-29. Summary of impairment of designated beneficial uses (i.e., water quality standards attainment) based on existing water quality conditions monitored at the Mainstem System projects over the 5-year period 2005 through 2009. (Note: “Official” identification of impaired water bodies is defined in State prepared Section 305(b) and Section 303(d) assessments – See Table 1-3.)

	Recreation[1]	Coldwater Aquatic Life	Warmwater Aquatic Life	Domestic Water Supply	Agricultural Water Supply	Industrial Water Supply
Fort Peck Lake	Unknown	Not Assigned[2]	Full Support	Full Support[9]	Full Support	Full Support
Fort Peck Dam Tailwaters	Unknown	Full Support	Full Support	Full Support	Full Support	Full Support
Lake Sakakawea	Unknown	Impaired[3]	Full Support	Full Support	Full Support	Full Support
Garrison Dam Tailwaters	Unknown	Threatened[4]	Threatened[4]	Full Support	Full Support	Full Support
Lake Oahe	Unknown	Full Support	Full Support	Full Support	Full Support	Full Support
Oahe Dam Tailwaters	Unknown	Impaired[5]	Full Support	Full Support	Full Support	Full Support
Lake Sharpe	Unknown	Impaired[6]	Full Support	Full Support	Full Support	Full Support
Big Bend Dam Tailwaters	Unknown	Not Assigned	Full Support	Full Support	Full Support	Full Support
Lake Francis Case	Unknown	Not Assigned	Full Support	Full Support	Full Support	Full Support
Fort Randall Dam Tailwaters	Unknown	Not Assigned	Threatened[4]	Full Support	Full Support	Full Support
Lewis and Clark Lake	Full Support	Not Assigned	Impaired[7] Threatened[8]	Full Support	Full Support	Full Support
Gavins Point Dam Tailwaters	Unknown	Not Assigned	Full Support	Full Support	Full Support	Full Support

(1) Water quality standards attainment for recreation is based on assessment of collected bacteria data.

(2) The State of Montana has not designated a coldwater aquatic life use to Fort Peck Lake. A coldwater fishery and associated aquatic life do exist in Fort Peck Lake and seemingly are an existing use. Monitored water quality conditions indicate that it is currently fully supported.

(3) Coldwater aquatic life in Lake Sakakawea is seemingly impaired by warm water temperatures and low dissolved oxygen levels during late summer. This is believed a result of reduced hypolimnetic volume associated with low pool elevations and the degradation of dissolved oxygen in the hypolimnion.

(4) Aquatic life uses in the Garrison and Fort Randall Dam tailwaters may be threatened by low dissolved oxygen levels during late summer. Water discharged from both dams is drawn from the bottom of Garrison and Fort Randall Reservoirs. The reservoirs thermally stratify during the summer and the lower depths of the hypolimnion experience dissolved oxygen degradation as the summer progresses.

(5) Lake Oahe thermally stratifies in the summer and coldwater aquatic life is supported in the reservoir’s hypolimnion. However, the power tunnel portals at Oahe Dam are located about 114 feet above the bottom of the reservoir and dam discharges during the summer commonly draw warmer water from the metalimnion and epilimnion – especially when pool elevations are low. Thus, water temperatures in the Oahe Dam tailwaters are not supportive of coldwater aquatic life during mid- to late-summer.

(6) Lake Sharpe generally does not exhibit significant thermal stratification in the summer; therefore, a coldwater hypolimnion does not usually form. The lack of significant summer thermal stratification at the reservoir is attributed to its relative shallowness and the high discharges released through Big Bend Dam associated with its operation to meet peak power demands. Due to the lack of significant summer thermal stratification, ambient water temperatures in Lake Sharpe are not cold enough to support coldwater permanent fish life propagation, as defined by State water quality criteria. Consideration should be given to reclassify Lake Sharpe for a warmwater permanent fish life propagation use based on a use attainability assessment of “natural conditions” regarding ambient water temperature.

(7) Warmwater aquatic life (i.e., aesthetics) is impaired due to nutrients based on monitored total phosphorus, total nitrogen, and chlorophyll *a* levels.

(8) Warmwater aquatic life is seemingly threatened by sedimentation of Lewis and Clark Lake as the volume loss from the “as-built” multiple use pool is approaching 25 percent (i.e., 23.8%).

(9) The District’s monitoring of ambient water quality conditions in Fort Peck Lake do not indicate impairment of domestic water supply. The District however defers to Montana’s assessment of drinking water as impaired, as the District does not monitor or review source water quality conditions of public drinking water facilities utilizing Fort Peck Lake as source water.

5.8.2 General Water Quality Conditions in the Reservoirs

Table 5-30 summarizes general water quality conditions at the Mainstem System reservoirs based on the water quality monitoring conducted over the 5-year period 2005 through 2009. The four largest reservoirs (i.e., Fort Peck, Garrison, Oahe, and Fort Randall) exhibit characteristics typical of dimictic lakes (Wetzel, 2001). The four reservoirs exhibit summer and winter thermal stratification separated by periods of complete mixing during the spring and fall turnover periods. A large quiescent hypolimnion forms during the summer in the three larger reservoirs (i.e., Fort Peck, Garrison, and Oahe) with a smaller hypolimnion forming in Fort Randall. The formation of a smaller hypolimnion in Fort Randall Reservoir, as compared to the three other reservoirs, is attributed to its lesser maximum depth and volume. Due to their shallower depths, Big Bend and Gavins Point Reservoirs appears to be discontinuous polymixic, with periods of summer thermal stratification forming and breaking down as climatic factors change. Wetzel (2001) identifies lakes as discontinuous cold polymictic if they are ice-covered part of the year and ice-free above 4°C during the warm season, and exhibit thermal stratification during the warm period for periods of several days to weeks but with irregular interruption by mixing. Big Bend Reservoir does not typically exhibit prolonged summer thermal stratification due to the high discharge rates that occur through Big Bend Dam for power production. Moderate hypolimnetic dissolved oxygen degradation regularly occurs in Garrison and Fort Randall Reservoirs. Only minor hypolimnetic dissolved oxygen degradation appears to occur in Fort Peck, Oahe, and Big Bend Reservoirs. Significant dissolved oxygen degradation can occur in Gavins Point Reservoir during the summer when thermal stratification persists. Water quality conditions of summer discharges from Garrison and Fort Randall Dams are highly correlated to dam discharge rates. This high degree of correlation of summer water quality conditions of discharged water with the dam discharge rate is not evident at the other four Mainstem System dams. The high degree of correlation at Garrison and Fort Randall Dams is attributed to each dam having a near-bottom withdrawal from their impounded reservoirs. The vertical extent of the withdrawal zone in these two reservoirs is dependent on the dam discharge rate. The lacustrine areas of the five upper reservoirs all appear to be mesotrophic, with only Gavins Point being in a eutrophic condition. The prevalence of major phytoplankton groups is similar in all six Mainstem System reservoirs, with diatoms being the most prevalent group.

5.8.3 Comparison of the Existing Coldwater Habitat Conditions in Fort Peck, Garrison, and Oahe Reservoirs

5.8.3.1 Water Temperature

Near-bottom water temperatures measured at the near-dam, deepwater monitoring sites in Fort Peck Lake, Lake Sakakawea, and Lake Oahe during the period May through October of 2005 through 2009 were plotted to compare hypolimnetic water temperatures of the three reservoirs (Plate 402Plate 402). In all 5 years, the near-bottom water temperatures measured in the three reservoirs were similar in May. The near-bottom temperature of all three reservoirs increased every year over the "summer" period. The relative rates at which the near-bottom water warmed in the three reservoirs remained fairly consistent over the 5 years; Garrison had the highest rate of warming, Oahe had the lowest, and the rate of warming of Fort Peck was in between (Plate 402). Bottom water temperatures measured in 2009 were appreciably cooler than those measured in 2005 through 2008. This is attributed to higher pool elevations (i.e., greater thermal mass to be heated) and possibly cooler summer weather conditions in 2009 (see Plate 82).

Table 5-30. Summary of general water quality conditions monitored at the Mainstem System reservoirs over the 5-year period 2005 through 2009. (Note: Record low pool levels occurred during the 5-year period due to severe drought in the western United States where the reservoirs are located.)

	Fort Peck	**Garrison**	**Oahe**	**Big Bend**	**Fort Randall**	**Gavins Point**
Maximum reservoir depth near the dam when pool elevation is at the top of Carryover Multiple Use Zone.	204 ft	168 ft	193 ft	75 ft	123 ft	48 ft
Minimum and maximum hourly pool elevation recorded during the 5-year period 2005 through 2009.	2196.2 ft-msl 2221.1 ft-msl	1805.6 ft-msl 1842.8 ft-msl	1569.7 ft-msl 1614.0 ft-msl	1419.1 ft-msl 1421.8 ft-msl	1336.5 ft-msl 1362.3 ft-msl	1204.4 ft-msl 1209.2 ft-msl
Maximum reservoir depth near the dam at the minimum and maximum pool elevation recorded during the 5-year period 2005 through 2009.	166 ft 191 ft	136 ft 173 ft	155 ft 199 ft	74 ft 77 ft	110 ft 136 ft	45 ft 50 ft
Extent of hypolimnion formed during summer thermal stratification period	Large (Plates 7-11)	Large (Plates 69-73)	Large (Plates 156-160)	Very Small (Plates 219-223)	Moderate (Plates 279-283)	Small (Plates 339-343)
Extent of dissolved oxygen degradation in the hypolimnion just prior to "fall turnover" of the reservoir	Minor (Plates 15-16)	Moderate (Plates 78-79)	Minor (Plates 165-166)	Minor (Plates 227-228)	Moderate (Plates 286-289)	Moderate (Plates 347-348)
Correlation of dam discharge water quality conditions to dam discharge rates during the summer	Low (Plates 35-54)	High (Plates 103-130)	Low (Plates 189-208)	Low (Plates 246-265)	High (Plates 308-326)	Low (Plates 377-396)
Lake trophic status[(1)]	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Eutrophic
Average TSI score[(2)]	48	49	46	50	49	59
Most prevalent phytoplankton group sampled[(3)]	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta
Percent of samples where Cyanobacteria was the most prevalent phytoplankton group based on collected biovolume[(3)]	12%	4%	4%	8%	4%	0%
Percent of samples where Cyanobacteria were 10% or more of the collected phytoplankton biovolume[(3)]	36%	8%	12%	28%	8%	8%

(1) Based on near-dam water quality conditions in the reservoir.
(2) TSI = Trophic State Index (see text for explanation). Based on near-dam water quality conditions in the reservoir.
(3) Based on phytoplankton samples collected near the dam of each reservoir.

Water temperature-depth profiles measured at the near-dam, deepwater locations at the three reservoirs were used to determine the depth at which water temperatures of 15°C or less occurred. Plate 403 shows a plot of the 15°C water temperature isopleths for Fort Peck Lake, Lake Sakakawea, and Lake Oahe for 2005 through 2009. All three reservoirs exhibited surface water temperatures at or below 15°C in May of all 5 years (Plate 403). After May of each year, the 15°C isopleths in all three reservoirs generally moved downward (i.e., 15°C water temperature occurred at a greater depth) through the "summer" period until fall turnover of the reservoirs occurred. The rate of decline of the 15°C isopleths at Garrison was greater than at Fort Peck and Oahe in 2005, 2008, and 2009 (Plate 403). In 2006 and 2007 the rate of decline of the 15°C isopleths was similar in all three reservoirs (Plate 403). The decreasing rate in the decline of the 15°C isopleths at Lake Sakakawea, in comparison to Fort Peck and Oahe Reservoirs, in 2006 and 2007 is attributed to the short-term water management measures implemented at Garrison Dam to enhance coldwater habitat in Lake Sakakawea. Water temperatures monitored in 2008 and 2009 are believed to be impacted by the high inflows to the reservoirs that occurred in late-spring and early summer.

The rate of hypolimnetic warming of the three reservoirs appears to be related to the depth of water withdrawal from the reservoir. Lake Sakakawea has the deepest level of withdrawal (i.e., 2 feet above the reservoir bottom) and, except for 2006 and 2007, had the highest rate of warming. Lake Oahe has the shallowest level of withdrawal (i.e., 114 feet above the reservoir bottom) and had the lowest rate of warming. Fort Peck Lake has an intermediary level of withdrawal (i.e., 65 feet above the reservoir bottom) and had an intermediate rate of warming. In 2006 and 2007, the implemented short-term water quality management measures at Garrison Dam (i.e., plywood barriers on trash racks) resulted in an intermediary level of withdrawal, and in 2006 and 2007 the rate of hypolimnetic warming at Lake Sakakawea was similar to Fort Peck Lake. The near-bottom withdrawal of water from Lake Sakakawea, absent the trash-rack plywood barriers, undoubtedly causes mixing within the hypolimnion as water is discharged through the dam and evacuated from lower levels of the hypolimnion. This mixing induces the transfer of heat within the reservoir's hypolimnion and into it from the metalimnion. The elevation of water withdrawal from Lake Oahe is generally at or above the thermocline, especially during low pool levels, and extensive mixing and warming of the hypolimnion is not induced. Water withdrawn from Fort Peck Lake and from Lake Sakakawea with the trash-rack plywood barriers in place is from the upper depths of the hypolimnion, and some withdrawal-induced mixing and warming of the hypolimnion may take place.

5.8.3.2 Dissolved Oxygen

As was done for water temperature, near-bottom dissolved oxygen concentrations measured at the near-dam, deepwater monitoring sites in Fort Peck Lake, Lake Sakakawea, and Lake Oahe during May through October of the 5-period 2005 through 2009 were plotted to compare the hypolimnetic dissolved oxygen conditions of the three reservoirs (Plate 404). For all 5 years, the near-bottom dissolved oxygen concentrations measured in Lake Sakakawea ended the summer period (i.e., just prior to fall turnover) with lower dissolved oxygen levels than the other two reservoirs (Plate 404). The hypolimnetic dissolved oxygen levels of all three reservoirs decreased every year over the summer period. The relative rates of dissolved oxygen degradation in the near-bottom water of the three reservoirs over the summer periods evaluated were somewhat consistent. The hypolimnetic dissolved oxygen degradation rates in Fort Peck Lake and Lake Oahe appeared similar and less those present in Lake Sakakawea (Plate 404). It is believed the near-bottom withdrawal of water at Lake Sakakawea may draw water with low dissolved oxygen levels to the dam from the middle reaches of the reservoirs faster than at Fort Peck Lake and Lake Oahe.

6 LOWER MISSOURI RIVER: GAVINS POINT DAM TO RULO, NE

6.1 CHANNEL CHARACTERISTICS AND TRIBUTARIES

The Missouri River between Gavins Point Dam (RM 811) and Rulo, NE (RM498) flows in an east-southeasterly to south-southeasterly direction. Major tributaries to the Missouri River below Gavins Point Dam, moving downstream, include: James River (South Dakota) at RM 801, Vermillion River (South Dakota) at RM 772, Big Sioux River (South Dakota and Iowa) at RM 734, Floyd River (Iowa) at RM 731, Little Sioux River (Iowa) at RM 669, Soldier River (Iowa) at RM664, Boyer River (Iowa) at RM 635, Platte River (Nebraska) at RM 595, Nishnabotna River (Iowa) at RM 542, and Tarkio River (Missouri) at RM 508. Extensive bed degradation has occurred in the upper areas of this Missouri River reach because river sediment is captured above Gavins Point Dam. Another factor is the substantial Missouri River channel shortening that occurred as part of the downstream Missouri River Bank Stabilization and Navigation Project. Gradual armoring of the riverbed has reduced the rate of channel degradation. Since 1965, approximately 10 feet of stage reduction has occurred for a discharge of 30,000 cfs in the Sioux City, IA area. During this period channel degradation of the Missouri River downstream in the Omaha, NE (RM 615.9) area has been non-existent. This reach of the Missouri River can be separated into three distinct sub reaches: the Missouri River National Recreational River, Kensler's Bend, and the Missouri River Navigation Channel reaches.

6.1.1 MISSOURI RIVER NATIONAL RECREATION RIVER REACH

The 59-mile reach of the Missouri River downstream of Gavins Point Dam starting at RM 811 down to Ponca, NE (RM 752) has been designated a National Recreational River under the Federal Wild and Scenic Rivers Act. This reach of the river has not been channelized by construction of dikes and revetments, and has a meandering channel with many chutes, backwater marshes, sandbars, islands, and variable current velocities. Snags and deep pools are also common. Although this portion of the river includes some bank stabilization structures, the river remains fairly wide. Bank erosion rates since the closure of Gavins Point Dam in 1956 have averaged 132 acres per year between Gavins Point Dam and Ponca, compared to a pre-dam rate of 202 acres per year. The rate of erosion had been declining since 1975 and then dramatically increased during the high flow years of 1995 through 1997.

6.1.2 KENSLER'S BEND REACH

The Kensler's Bend reach of the Missouri River extends from Ponca, Nebraska (RM 752) to above Sioux City, IA (RM 735). The Missouri River banks have been stabilized with dikes and revetments through this reach, but it has not been channelized.

6.1.3 MISSOURI RIVER NAVIGATION CHANNEL REACH

The reach of the Missouri River from the end of the Kensler's Bend reach (RM 735) to Rulo, NE (RM 498) has been modified over its entire length by an intricate system of dikes and revetments designed to provide a continuous navigation channel without the use of locks and dams. This reach is managed by the Corps under the Missouri River Bank Stabilization and Navigation Project. In addition to the primary authorization to maintain a navigation channel (9 ft deep by 300 ft wide) downstream from Sioux City, IA to the mouth of the Missouri River, there are authorizations to stabilize the river's banks.

6.2 FLOW REGULATION

Releases from Gavins Point Dam follow the same pattern as those from Fort Randall Dam because there is little active storage in Lewis and Clark Lake. Releases from both dams are based on the amount of water in Mainstem System storage, which governs how much water will be released to meet service demands in the portion of the lower Missouri River from Sioux City, IA to St. Louis, MO. Constraints for flood control, threatened and endangered bird nesting, and fish spawning also are factors governing releases. Releases from Gavins Point Dam generally fall into three categories: navigation, flood evacuation, and nonnavigation releases.

6.2.1 MAINSTEM SYSTEM SERVICE LEVEL

To facilitate appropriate application of multipurpose regulation criteria to the Mainstem System, a numeric "service level" has been adopted since the Mainstem System was first filled in 1967. Quantitatively, a full service level approximates the water release rate necessary to achieve a normal 8-month navigation season with average downstream tributary flow contributions. For "full-service" and "minimum service" levels, the numeric service level values are, 35,000 cfs (cubic feet per second) and 29,000 cfs, respectively. This service level is used for selection of appropriate flow target values at previously established downstream control locations on the Missouri River. There are four flow target locations selected below Gavins Point Dam to assure that the Missouri River has adequate water available for the entire downstream reach to achieve regulation objectives. The four flow target locations and their flow target discharge deviation from service levels are: Sioux City (-4,000 cfs); Omaha (-4,000 cfs); Nebraska City (+2,000 cfs); and Kansas City (+6,000 cfs). A full-service level of 35,0000 cfs results in target discharges of 31,000 cfs at Sioux City and Omaha; 37,000 cfs at Nebraska City; and 41,000 cfs at Kansas City. Similarly, a minimum-service level of 29,000 cfs results in target values of 6,000 cfs less than the full-service levels at the four target locations. The relation of service levels to the volume of water in Mainstem System storage is as follows:

Date	Water in Mainstem System Storage (MAF)	Service Level (cfs)
March 15	54.5 or more*	35,000 (full-service)
March 15	31.0 to 49.0*	29,000 (minimum-service)
March 15	31.0 or less	No Service
July 1	57.0 or more*	35,000 (full-service)
July 1	50.5 or less*	29,000 (minimum-service)
* Straight-line interpolation defines intermediate service levels between full and minimum service.		

The length of the navigation season is determined by the volume of water in storage as follows:

Date	Water in Mainstem System Storage (MAF)	Season Closure Date at Mouth of Missouri River
March 15	Less than 31.0	No season
July 1	51.5 or more*	December 1 (8-month season)
July 1	41.0 to 46.8*	November 1 (7-month season)
July 1	36.5 or less*	October 1 (6-month season)
* Straight-line interpolation defines intermediate closure date between given values.		

6.2.2 HISTORIC FLOW RELEASES

In the navigation season, which generally runs from April 1 through November 30, releases from Gavins Point Dam are generally 25,000 to 35,000 cfs. In the winter, releases are in the 10,000- to 20,000-

cfs range. In wet years with above-normal upstream inflows, releases are higher to evacuate flood control storage space in upstream reservoirs. Maximum winter releases are generally kept below 24,000 cfs to minimize downstream flooding problems caused by ice jams in the lower river. During the 1987 to 1993 and the 2000 to 2008 droughts, nonnavigation releases were generally in the 8,000- to 9,000- cfs range immediately following the end and preceding the start of the navigation season. During cold weather, releases were increased up to 15,000 cfs, but generally averaged 12,000 cfs over the 3-month winter period from December through February.

6.2.3 FLOW RELEASES FOR WATER QUALITY MANAGEMENT

Generally, Mainstem System release levels necessary to meet downstream water supply purposes exceed the minimum release levels necessary to meet minimum downstream water quality requirements. Tentative flow requirements for satisfactory water quality were first established by the U.S. Public Health Service and presented in the 1951 Missouri Basin Inter-Agency Committee Report on Adequacy of Flows in the Missouri River. These requirements were used in Mainstem System regulation until revisions were made in 1969 by the Federal Water Pollution Control Administration. The Missouri River minimum daily flow requirements for water quality (i.e., dissolved oxygen) that are given below were initially established by the Federal Water Pollution Control Administration in 1969. They were reaffirmed by the U.S. Environmental Protection Agency in 1974 after consideration of: 1) the current status of PL 92-500 programs for managing both point and non-point sources discharging into the river, and 2) the satisfactory adherence to the dissolved-oxygen concentration of 5.0 mg/l. The minimum daily flow requirements listed below are used for Mainstem System regulation purposes.

Location	Dec, Jan, Feb	Mar, Apr	May	Jun, Jul, Aug, Sep	Oct, Nov
Sioux City, IA	1,800 cfs	1,370 cfs	1,800 cfs	3,000 cfs	1,350 cfs
Omaha, NE	4,500 cfs	3,375 cfs	4,500 cfs	7,500 cfs	3,375 cfs
Kansas City, MO	5,400 cfs	4,050 cfs	5,400 cfs	9,000 cfs	4,050 cfs

Low flows in the Missouri River downstream from Gavins Point Dam may affect the ability of powerplants on this reach to meet National Pollutant Discharge Elimination System (NPDES) permit thermal limits for discharging cooling water back into the Missouri River.

6.2.4 FLOW TRAVEL TIMES

For purposes of scheduling releases, approximate open water travel times from Gavins Point Dam are 1.5 days to Sioux City; 3 days to Omaha; 3.5 days to Nebraska City; 5.5 days to Kansas City; and 10 days to the mouth of the Missouri River near St. Louis.

6.3 HISTORIC FLOW CONDITIONS (1967 TO 2009)

Historic flow conditions for the period 1967 through 2009 were determined from Corps and USGS gaging sites along the Missouri River from Gavins Point Dam to Rulo, NE. The gaging sites include: Gavins Point Dam; Omaha; Nebraska City; and Rulo. Box plots showing the distribution of the mean daily flows measured over the 43-year period are shown in Figure 6-1.

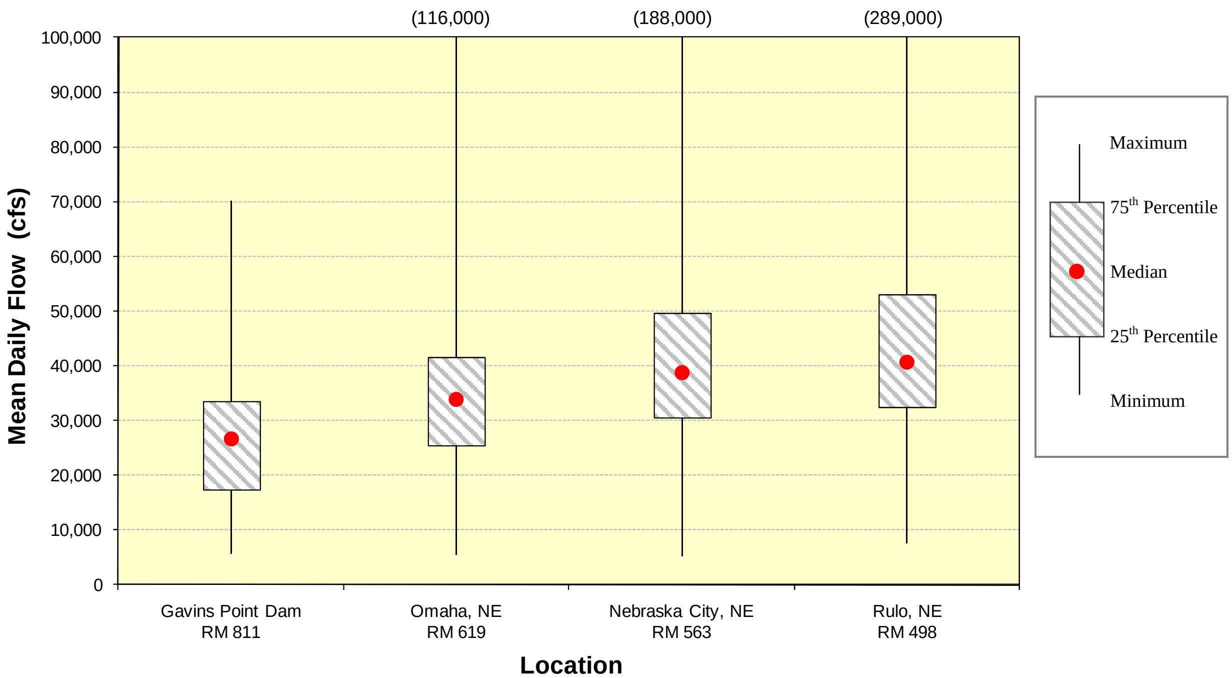

Figure 6-1. Distribution of mean daily flows recorded at gaging sites on the Missouri River at Gavins Point Dam, Omaha, NE, Nebraska City, NE, and Rulo, NE during the 43-year period of 1967 through 2009.

6.4 NATIONAL RECREATION RIVER DESIGNATION PURSUANT TO THE FEDERAL WILD AND SCENIC RIVERS ACT

The 59-mile "natural-channel" reach from Gavins Point Dam to Ponca State Park, NE has been designated as a National Recreational River under the Federal Wild and Scenic Rivers Act (WSRA). The National Park Service (NPS) manages the reach under the WSRA. The justification that supported that this reach of the Missouri River be protected as a recreational river identified its outstanding remarkable recreational, fish and wildlife, aesthetic, historical, and cultural values. Under the WSRA, the U.S. Department of Interior (i.e., NPS) is mandated to administer this reach in a manner that will protect and enhance these values for the benefit and enjoyment of present and future generations.

6.5 STATE DESIGNATIONS AND LISTINGS PURSUANT TO THE FEDERAL CLEAN WATER ACT

Pursuant to the Federal Clean Water Act (CWA), the States of South Dakota, Nebraska, Iowa, and Missouri have designated water quality-dependent beneficial uses, in their State water quality standards, for appropriate reaches of the Missouri River downstream of Gavins Point Dam to Rulo, NE. South Dakota has designated the following uses for all of the Missouri River within the state downstream of Gavins Point Dam: primary contact recreation, warmwater fishery, drinking water supply, and industrial water supply. Nebraska has designated the following uses to the entire length of the Missouri River in Nebraska: primary contact recreation, warmwater aquatic life, agricultural water supply, and aesthetics. It has designated the use of drinking water supply to the river downstream of the confluence of the Niobrara River, and industrial water supply to the river downstream of the confluence of the Big Sioux River. Nebraska has also designated the reach between Gavins Point Dam and Ponca State Park as Outstanding State Resource Waters for "Tier 3" protection under the State's water quality standard's antidegradation policy. Iowa has designated the following uses to all of the Missouri River in the state: primary contact recreation, warmwater fishery, and high quality state resource water. It has also

designated the use of drinking water supply to the river in the area of Council Bluffs, IA. Missouri has designated the following uses to the river: primary contact recreation, warmwater fishery, drinking water supply, agricultural water supply, and industrial water supply. The States of Nebraska, Iowa, and Missouri have listed the Missouri River on their State's Section 303(d) list of impaired waters. The pollutant/stressors identified are pathogens, siltation, habitat loss, Dieldrin, PCBs, and arsenic. The source of siltation and habitat loss is identified as hydrologic modifications and channelization. The source of Dieldrin and PCBs is residual contamination, as both substances have been banned since the 1980's. The identified sources for the pathogens are municipal point sources, agriculture, and urban runoff.

6.6 EXISTING WATER QUALITY CONDITIONS

The Omaha District, in cooperation with the Nebraska Department of Environmental Quality (NDEQ), conducted fixed-station water quality monitoring at seven sites along the Missouri River from Gavins Point Dam to Rulo, NE during the 5-year period of 2005 through 2009. The location of the seven sites were Gavins Point Dam tailwaters (site GPTRRTW1); near Maskell, NE (site MORRR0774); near Ponca, NE (site MORRR0753); at Decatur, NE (site MORRR0691); at Omaha, NE (site MORRR0619); at Nebraska City, NE (site MORRR0563); and at Rulo, NE (site MORRR0498) (Figure 6-2).

6.6.1 STATISTICAL SUMMARY AND COMPARISON TO APPLICABLE WATER QUALITY STANDARDS CRITERIA

Water quality samples at the seven sites were collected monthly from October through March and monthly to biweekly from April through September. Plate 405, Plate 406, Plate 407, Plate 408, Plate 409, Plate 410, and Plate 411 summarize the water quality conditions that were monitored at the seven sites: GPTRRTW1, MORRR0774, MORRR0753, MORRR0691, MORRR0619, MORRR0563, and MORRR0498 during the 5-year period 2005 through 2009. A review of these results indicated no major water quality concerns. It is noted that one extremely high aluminum value was measured from the Missouri River at Rulo, NE (site MORRR0498) (Plate 411). Although this measurement is believed an outlier, future aluminum monitoring results will be assessed to evaluate the situation.

6.6.2 LONGITUDINAL VARIATION IN WATER QUALITY

The levels of selected parameters measured at each of the seven monitoring sites along the lower Missouri River over the 5-year period 2005 through 2009 were depicted as box plots. The parameters plotted include dissolved oxygen, pH, specific conductance, chloride, turbidity, total suspended solids, chemical oxygen demand, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, total nitrate-nitrite nitrogen, and total phosphorus (Plate 412). For comparison purposes, box plots for the individual parameters measured at each of the seven sites are arranged relative to their respective location in an upstream to downstream order (i.e., GPTRRTW1 = RM811, MORRR0774 = RM774, MORRR0753 = RM753, MORR0691 = RM691, MORR0619 = RM619, MORR0563 = RM563, and MORR0498 = RM498). Four longitudinal trends were categorized based on the constructed longitudinal box plots: 1) parameter exhibits no observable longitudinal trend, 2) parameter slightly decreases in a downstream direction, 3) parameter slightly increases in a downstream direction, and 4) parameter greatly increases in a downstream direction. Parameters that exhibited no observable longitudinal trend included pH, specific conductance, and total ammonia (Plate 412). Dissolved oxygen is the only parameter that slightly decreased in a downstream direction (Plate 412). Parameters that slightly increased in a downstream direction included chloride, chemical oxygen demand, total organic carbon, and total Kjeldahl nitrogen (Plate 412). Parameters that greatly increased in a downstream direction included turbidity, total suspended solids, nitrate-nitrite nitrogen, and total phosphorus (Plate 412).

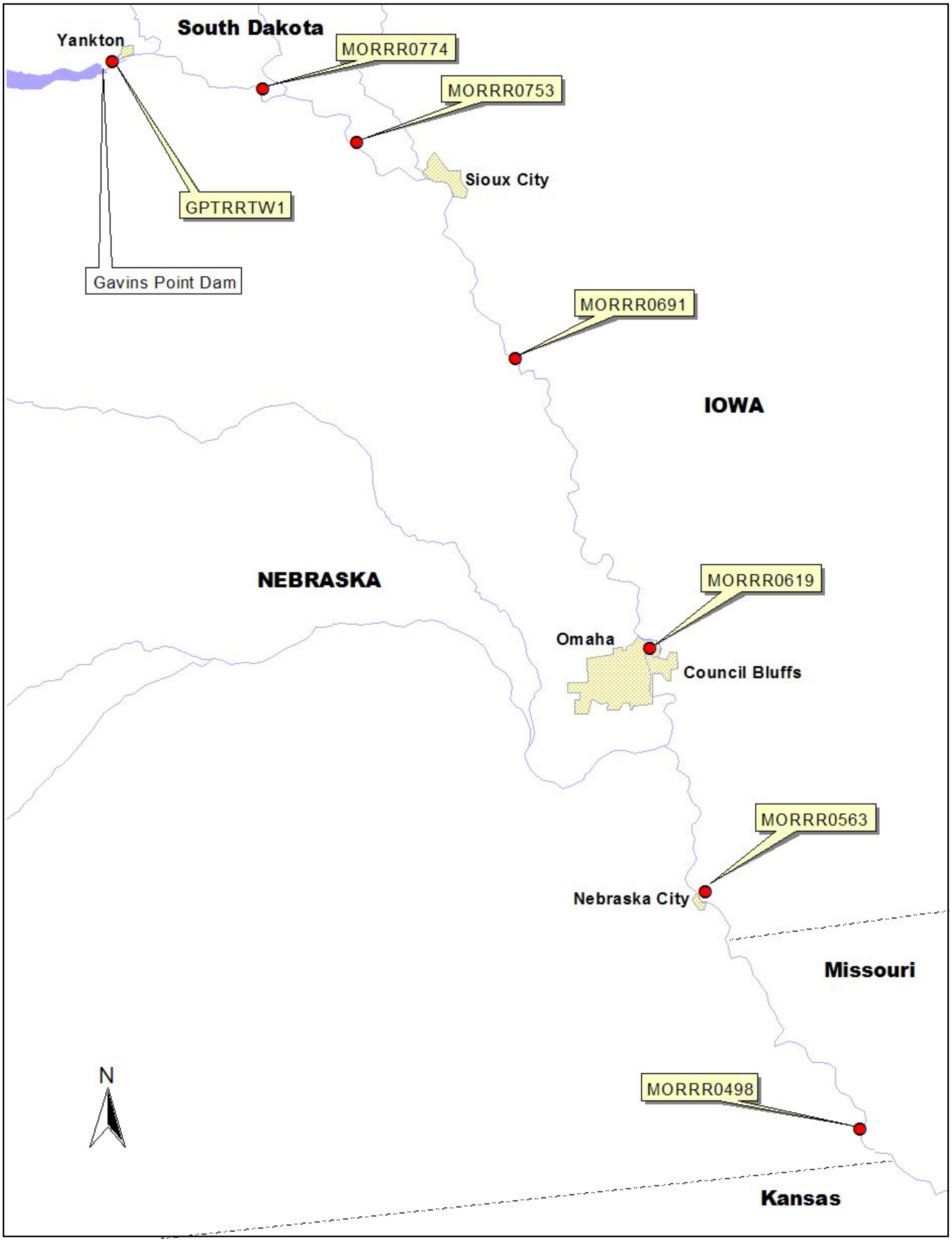

Figure 6-2. Locations of water quality monitoring sites along the Missouri River from Gavins Point Dam to Rulo, NE.

6.6.3 NUTRIENT FLUX CONDITIONS

Nutrient flux rates along the lower Missouri River from the Gavins Point Dam tailwaters to Rulo, NE were calculated for the 5-year period 2005 through 2009. The calculated flux rates were based on near-surface water quality samples collected at the seven monitoring locations and the instantaneous flow conditions at the time of sample collection (Table 6-1, Table 6-2, Table 6-3, Table 6-4, Table 6-5, Table 6-6, and Table 6-7). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) could seemingly be higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the flux rates given for total phosphorus and total organic carbon in the below Tables should be considered minimum estimates with the actual flux rates being potentially higher.

Table 6-1. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at the Gavins Point tailwaters (i.e., site GTPRRTW1) over the 5-year period 2005 through 2009.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	79	79	79	78	79	77
Mean	17,886	0.0369	0.2823	0.0492	0.0229	1.7314
Median	17,276	0.0227	0.2221	0.0321	0.0195	1.5654
Minimum	8,000	n.d.	n.d.	n.d.	n.d.	0.7128
Maximum	30,963	0.2527	1.3260	0.2718	0.0957	4.6382

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

Table 6-2. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Maskell, NE (i.e., site MORRR0774) over the 5-year period 2005 through 2009.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	64	64	64	64	64	62
Mean	20,752	0.0413	0.3580	0.0841	0.0487	2.0758
Median	22,222	0.0214	0.2945	0.0519	0.0356	2.1827
Minimum	9,161	n.d.	n.d.	n.d.	n.d.	0.5718
Maximum	31,274	0.2465	0.9048	0.5503	0.2015	4.2766

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

Table 6-3. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Ponca, NE (i.e., site MORRR0753) over the 5-year period 2005 through 2009.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	65	65	65	65	65	63
Mean	21,038	0.0434	0.4357	0.0747	0.0749	2.3764
Median	22,757	0.0218	0.3339	0.0256	0.0495	2.3990
Minimum	9,247	n.d.	0.0970	n.d.	n.d.	0.7571
Maximum	32,704	0.2688	1.5858	0.6820	0.3310	5.3941

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

Table 6-4. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Decatur, NE (i.e., site MORRR0691) over the 5-year period 2005 through 2009.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	77	77	77	76	77	74
Mean	24,314	0.0710	0.7320	0.8155	0.1468	2.9593
Median	25,400	0.0381	0.5343	0.4895	0.0902	2.8531
Minimum	11,500	n.d.	0.1811	n.d.	n.d.	0.7140
Maximum	42,400	0.4969	4.6106	5.8897	1.0123	10.8592

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

Table 6-5. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Omaha, NE (i.e., site MORRR0619) over the 5-year period 2005 through 2009.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	78	78	78	77	78	76
Mean	27,430	0.0853	1.0228	1.4608	0.2954	3.5784
Median	28,000	0.0355	0.6394	0.8628	0.1254	3.0200
Minimum	11,600	n.d.	n.d.	n.d.	0.0228	1.0385
Maximum	58,400	0.7718	6.6808	7.7722	3.3150	16.8027

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

Table 6-6. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Nebraska City, NE (i.e., site MORRR0563) over the 5-year period 2005 through 2009.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	79	79	79	78	79	77
Mean	34,432	0.1379	1.5875	1.8062	0.5046	4.7309
Median	33,750	0.0840	0.9220	1.3088	0.2291	3.3736
Minimum	16,000	n.d.	0.3263	0.0407	0.0550	1.2460
Maximum	117,000	0.9424	12.7881	10.9328	5.6321	26.5038

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

Table 6-7. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Rulo, NE (i.e., site MORRR0498) over the 5-year period 2005 through 2009.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	78	78	78	77	78	76
Mean	35,917	0.1186	1.4262	2.0827	0.4803	4.4863
Median	33,475	0.0648	0.9382	1.5495	0.2411	3.3661
Minimum	17,500	n.d.	0.3270	0.0295	0.0595	0.9682
Maximum	131,000	0.9066	8.4613	12.2410	5.2883	25.4971

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

6.7 WATER TEMPERATURES MONITORED ALONG THE LOWER MISSOURI RIVER IN 2009

Mean daily water temperatures were calculated from USGS and USACE data recorded in 2009 at monitoring locations along the lower Missouri River. Plate 413 plots 2009 mean daily water temperatures for the Missouri River at Gavins Point Dam; Sioux City, IA; Decatur, NE; Omaha, NE; and St. Joseph, MO. Generally, mean daily water temperatures in the Missouri River are about 3 to 4° C warmer at St. Joseph, MO as compared to the discharges from Gavins Point Dam (Plate 413).

6.8 ESTIMATED CURRENT NUTRIENT CONCENTRATIONS AND MEAN DAILY LOADS ALONG THE MISSOURI RIVER IN THE OMAHA DISTRICT

Nutrient (i.e., nitrate-nitrite nitrogen, total nitrogen, and total phosphorus) concentrations and mean daily loads for the Missouri River at selected locations in the Omaha District were compiled from monitoring conducted during the 5-year period of 2005 through 2009. The monitored locations along the Missouri River included the following 16 sites (listed in an upstream to downstream order with the river mile given): 1) near Landusky, MT [RM 1921]; 2) at Fort Peck Dam [RM 1771]; 3) Near Williston, ND [RM 1553]; 4) at Garrison Dam [RM 1389]; 5) at Bismarck, ND [RM 1315]; 6) at Oahe Dam [RM 1072]; 7) at Big Bend Dam [RM 986]; 8) at Fort Randall Dam [RM 879]; 9) near Verdel, NE [RM 851]; 10) at Gavins Point Dam [RM 811]; 11) near Maskell, NE [RM 774]; 12) near Ponca, NE [RM 753]; 13) at

Decatur, NE [RM 691]; 14) at Omaha, NE [RM 619]; 15) at Nebraska City, NE [RM 563]; and 16) at Rulo, NE [RM 498]. The samples collected at the mainstem dams were collected at the respective powerplants and are representative of the water discharged from the dams. The other samples collected along the Missouri River were grab samples representative of near-surface conditions.

6.8.1 EXISTING NUTRIENT CONCENTRATIONS MEASURED ALONG THE MISSOURI RIVER

Box plots were constructed from the total nitrate-nitrite nitrogen, total nitrogen, and total phosphorus concentrations measured along the Missouri River at the 16 locations during the 5-year period (Figure 6-3). As seen in Figure 6-3, there is a significant increase in nitrate-nitrite nitrogen levels downstream of Gavins Point Dam; especially downstream of Ponca, NE (RM753). Large cities (i.e., Sioux City, IA and Omaha, NE) and tributary streams draining areas of intensive agriculture are located downstream of Gavins Point Dam. An increase in total phosphorus levels is also seen downstream of Gavins Point Dam (Figure 6-3). Higher levels of total phosphorus were also measured in the Missouri River near Landusky, MT (RM1921 – inflow to Fort Peck Lake) and Williston, ND (RM1553 – inflow to Lake Sakakawea). It is noted that the Yellowstone River enters the Missouri River downstream of Fort Peck Dam and upstream from Williston, ND.

6.8.2 EXISTING NUTRIENT LOADINGS ESTIMATED ALONG THE MISSOURI RIVER

Loadings for total nitrate-nitrite nitrogen, total nitrogen, and total phosphorus were estimated for the Missouri River at the 16 locations based on the powerplant and near-surface sampling data collected over the 5-year period. Daily loadings were calculated from the instantaneous flux rates determined for the sites. It is recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Thus, the calculated flux rates from the near-surface sampling could appreciably under estimate the total phosphorus loadings. The powerplant samples are representative of the water discharged from the dams and give an unbiased estimate of total phosphorus loadings. Loadings for nitrate-nitrite and total nitrogen are believed to be unbiased in this regard as these nitrogen constituents do not tend to be particulate associated.

Figure 6-4 plots the estimated mean daily loads in tons per day at the 16 sites along the Missouri River. The six mainstem reservoirs trap nutrients along the Missouri River and function as nutrient sinks. Nutrient loadings are significant reduced immediately downstream of the six Missouri River mainstem reservoirs (Figure 6-4). The increased loading in the Missouri River at Williston, ND is attributed to the inflow of the Yellowstone River which has no major reservoirs along its entire reach to Yellowstone National Park. The greatly increasing nutrient loads in the Missouri River downstream of Gavins Point Dam are attributed to point and nonpoint source nutrient input to the river.

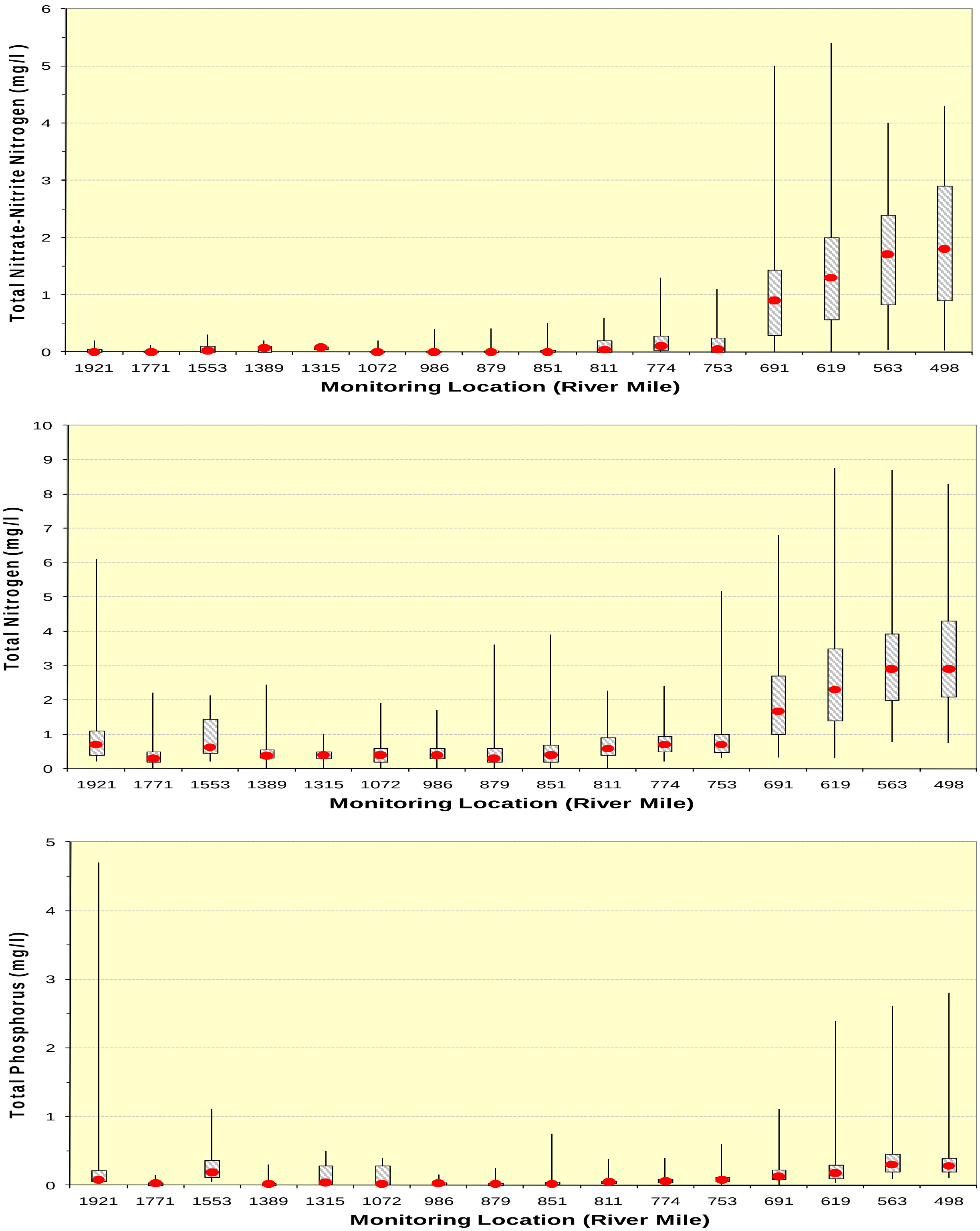

Figure 6-3. Distribution of measured concentrations of total nitrate-nitrite nitrogen, total nitrogen, and total phosphorus at 16 locations along the Missouri River from Landusky, MT (RM1921) to Rulo, NE (RM498) during the 5-year period 2005 through 2009. (Box plots represent minimum, 25th percentile, 75th percentile, and maximum. Red dot is the median value).

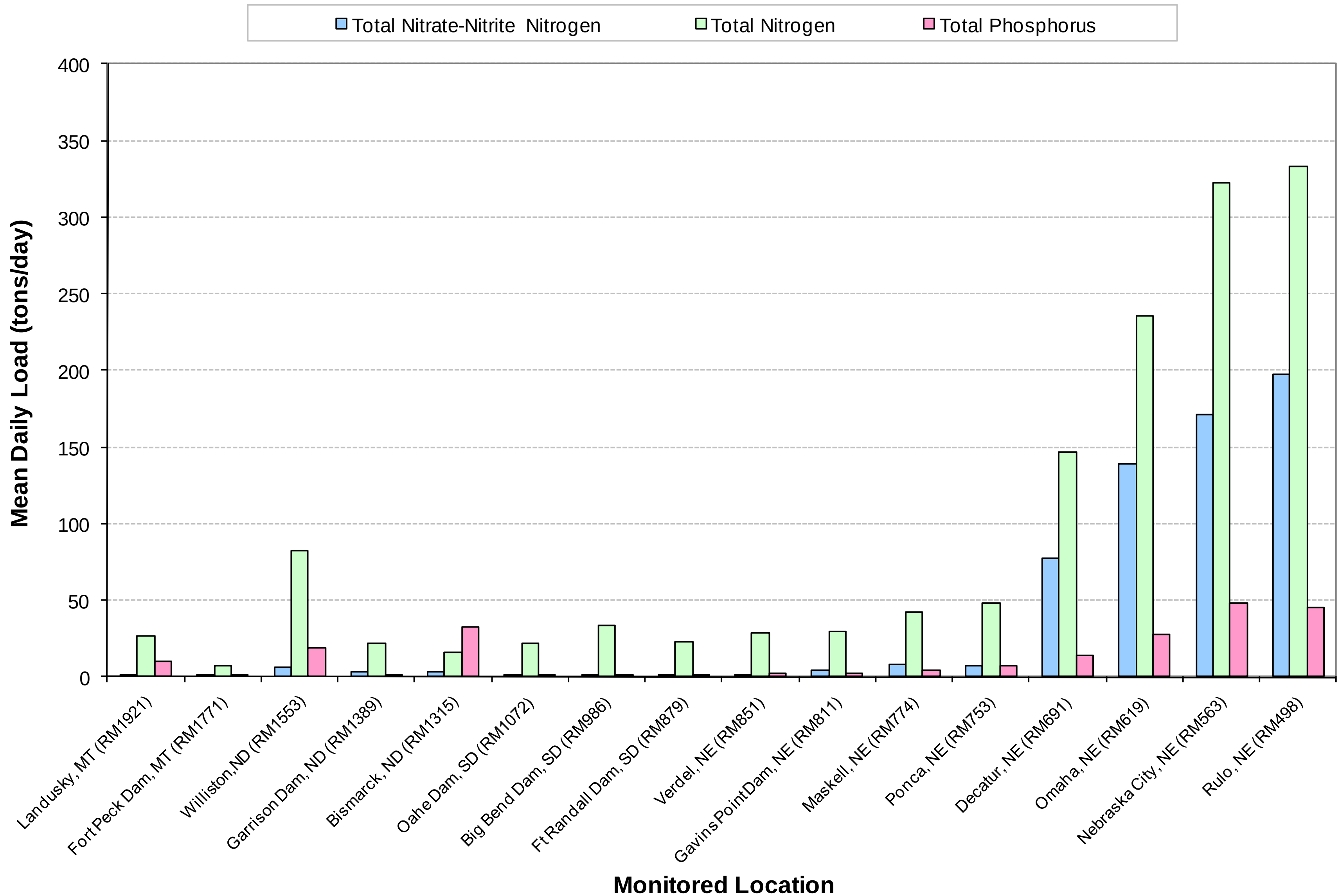

Figure 6-4. Estimated mean daily loads (tons/day) for total nitrate-nitrite nitrogen, total nitrogen, and total phosphorus along the Missouri River from near Landusky, MT (RM1921) to Rulo, NE (RM498) for the 5-year period 2005 through 2009.

7 MAINSTEM ANCILLARY LAKES

7.1 LAKE AUDUBON

7.1.1 BACKGROUND INFORMATION

7.1.1.1 Lake Description

Lake Audubon is a sub-impoundment of Lake Sakakawea that is impounded by the Snake Creek Dam. Lake Audubon is located 12 miles northeast of Garrison Dam near the town of Garrison, ND. The Snake Creek Dam was constructed in 1954 with the primary purpose of relocating transportation and utility services inundated by the creation of Lake Sakakawea. A future purpose of Lake Audubon was to facilitate diversion for the purposes of irrigation, water supply, and pollution abatement. Maintenance of a stable sub-impoundment in the Snake River arm of Lake Sakakawea for wildlife and recreational development was defined as a desirable feature. The Snake River Dam has a crest elevation of 1865 ft-msl, and Lake Audubon pool levels are normally kept at about 1847 ft-msl in the summer and 1845 ft-msl in the winter. At pool elevation 1847 ft-msl, Lake Audubon has a surface area of approximately 18,780 acres. The lake is operated in cooperation with the U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, and the North Dakota Game and Fish Department.

7.1.1.2 Water Quality Standards and Section 303(d) Listings

Pursuant to the Federal CWA, the State of North Dakota has designated Lake Audubon as a Class 2 lake. As such, the lake is to be suitable for the propagation and maintenance of a cool-water fishery (i.e., northern pike and walleye) and associated biota; swimming, boating, and other water recreation; irrigation; stock watering; wildlife; and for municipal or domestic use after appropriate treatment. The State of North Dakota has not placed the lake on the State's Section 303(d) list of impaired waters, but has issued a statewide fish consumption advisory, which applies to Lake Audubon, due to mercury concerns.

7.1.1.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Lake Audubon since 1980. Figure 7-1 shows the location at Lake Audubon that has been monitored for water quality during the 5-year period 2005 through 2009. The near-dam site was monitored in 2006 and 2009. Water quality monitoring of Lake Audubon is currently on a 3-year cycle and it is next scheduled to be monitored in 2012.

7.1.2 EXISTING WATER QUALITY CONDITIONS

7.1.2.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 414 summarizes the water quality conditions that were monitored in Lake Audubon at the near-dam, deepwater ambient monitoring site (i.e., site AUDLKND1) during 2006 and 2009. A review of these results indicated no water quality concerns.

Figure 7-1. Location of water quality monitoring site at Lake Audubon.

7.1.2.2 <u>Summer Thermal Stratification</u>

Existing summer thermal stratification was assessed for Lake Audubon, based on monitoring results obtained at the near-dam, deepwater ambient monitoring site (i.e., site AUDLKND1) during 2006 and 2009. Temperature depth profiles were constructed from water quality data collected during the summer months (Plate 415). It appears a temperature-depth gradient occasionally occurs in Lake Audubon in the near-dam lacustrine area during the summer (Plate 415). When temperature stratification occurred, a thermocline was present near the lake. This indicates the reservoir is probably polymixic. During periods of calm weather in the summer, Lake Audubon likely develops a slight thermal stratification. The thermal stratification seemingly breaks down under windier conditions, given the shallow depth of the reservoir (i.e., 16 meters), allowing the reservoir to mix throughout the water column.

7.1.2.3 <u>Summer Dissolved Oxygen Conditions</u>

Existing summer dissolved oxygen conditions were assessed for Lake Audubon based on monitoring results obtained at the near-dam, deepwater ambient monitoring site during 2006 and 2009. Dissolved oxygen depth profiles were constructed from water quality data collected during the summer months (Plate 416). The measured summer dissolved oxygen-depth profiles exhibited some variability with depth. On occasions, low dissolved oxygen concentrations were measured near the reservoir bottom. The variability of the summer dissolved oxygen-depth profiles is attributed to the probable polymictic nature of the lake. When thermal stratification of the reservoir develops in the summer, significant dissolved oxygen degradation occurs in the near-bottom area of the hypolimnion. The lowest dissolved oxygen concentration measured was 1.7 mg/l, and was measured near the reservoir bottom on July 25, 2006.

7.1.2.4 <u>Lake Trophic Status</u>

Trophic State Index (TSI) values for Lake Audubon were calculated from monitoring data collected during 2006 and 2009 at the near-dam, ambient monitoring site (i.e., site AUDLKND1). Table 7-1 summaries the TSI values calculated for the lake. The TSI values indicate that the near-dam lacustrine area of Lake Audubon is in a moderately eutrophic state.

Table 7-1. Summary of Trophic State Index (TSI) values calculated for Lake Audubon for 2006 and 2009.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	8	50	54	37	57
TSI(TP)	9	54	60	41	76
TSI(Chl)	8	49	43	40	50
TSI(Avg)	7	51	52	44	57

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values irregardless of the parameters available to calculate the average.

Note: See Section 4.1.4 for discussion of TSI calculation.

7.1.2.5 <u>Impairment of Designated Water Quality Beneficial Uses</u>

Based on the State of North Dakota's impairment assessment methodology (Section 4.1.6.3), the water quality conditions monitored in Lake Audubon during 2006 and 2009 do not indicate any impairment of any designated water quality dependent beneficial uses.

7.1.3 WATER QUALITY TRENDS (1980 THROUGH 2009)

Water quality trends over the 30-year period of 1980 through 2009 were determined for Lake Audubon for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the lake during the months of May through October at the near-dam monitoring site (i.e., site AUDLKND1). Plate 417 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., α = 0.05). For the assessment period, Lake Audubon exhibited significant trends for chlorophyll *a* (decreasing) and TSI (decreasing) (Plate 417). No significant trends were detected for Secchi depth and total phosphorus (Plate 417). Over the 30-year period, the lake has generally remained in a moderately eutrophic state (Plate 417).

7.2 LAKE POCASSE

7.2.1 BACKGROUND INFORMATION

7.2.1.1 Lake Description

Lake Pocasse is a sub-impoundment of Lake Oahe on Spring Creek that is impounded by the Spring Creek Dam. Lake Pocasse is located in Campbell County, SD, near the town of Pollock. The Spring Creek Dam was built in lieu of a road relocation with a bridge spanning Spring Creek. The purpose of the sub-impoundment was to provide lake and marsh habitat for fish and wildlife management on the Spring Creek bottoms within the Lake Oahe pool area. In October 1962, a National Wildlife Refuge was established in the Spring Creek Bottoms, which includes Lake Pocasse. The U.S. Fish and Wildlife Service is responsible for the maintenance and management of wildlife habitat at Lake Pocasse. At the top of the multi-purpose pool (elevation 1614 ft-msl), Lake Pocasse has a surface area of approximately 1,545 acres and a volume of 7,100 acre-feet

7.2.1.2 Water Quality Standards and Section 303(d) Listings

The State of South Dakota has designated the following water quality-dependent beneficial uses for Lake Pocasse in the State's water quality standards: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, fish and wildlife propagation, and stock watering. The State of South Dakota has placed Lake Pocasse on the State's Section 303(d) list of impaired waters as a category 5 waterbody. The identified impaired use is warmwater permanent fish life, with the impairment due to eutrophication attributable to nonpoint source pollution. The State has not issued a fish consumption advisory for the lake.

7.2.1.3 Ambient Water Quality Monitoring

The District has not historically monitored water quality conditions at Lake Pocasse. In 2006, the District initiated a 3-year cycle to monitor water quality conditions at the lake. However, low water levels prevented the District from monitoring Lake Pocasse in 2006. The District did conduct water quality monitoring at the lake in 2009, and is planning to again monitor the lake in 2012. Figure 7-2 shows the water quality monitoring location at Lake Pocasse.

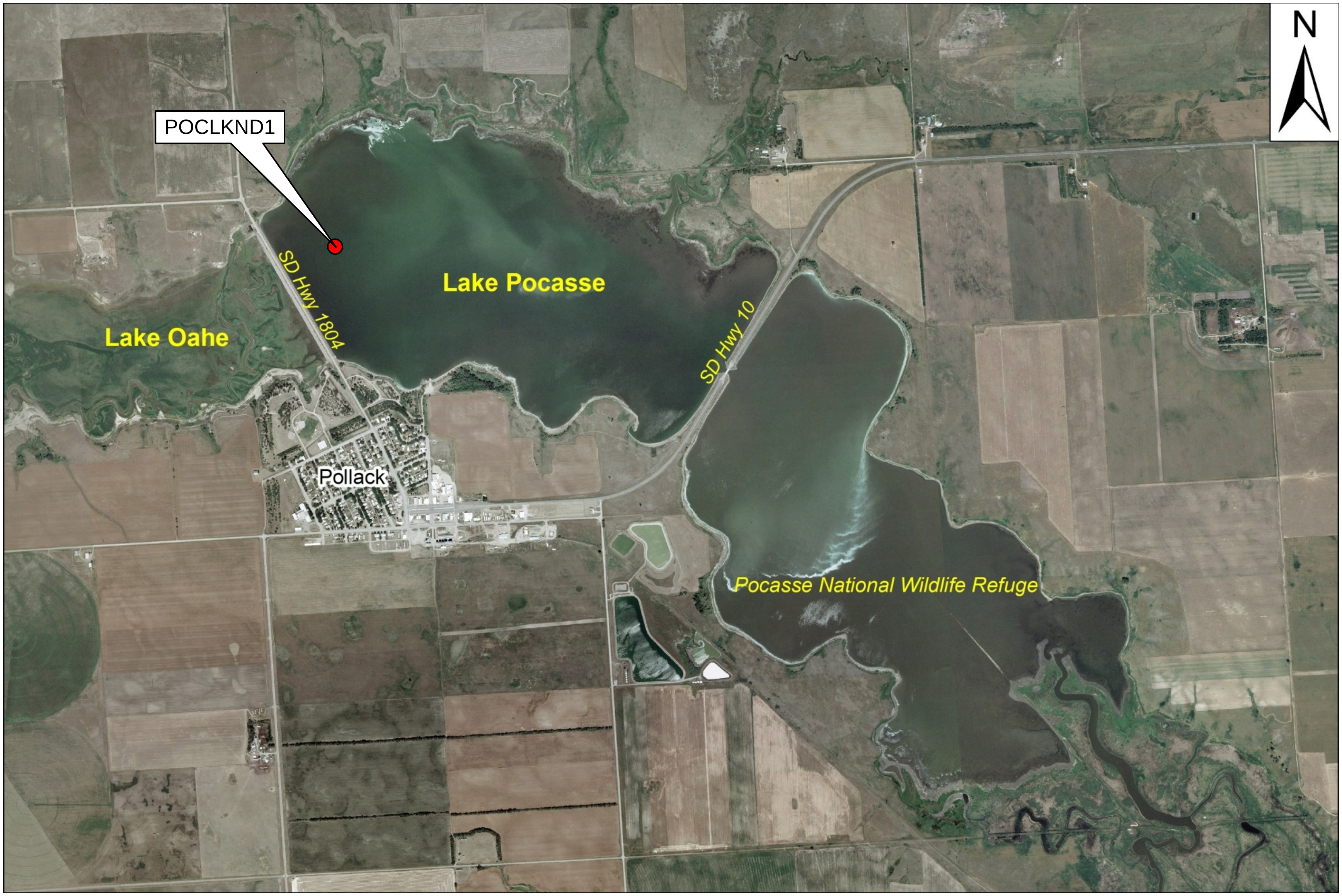

Figure 7-2. Location of water quality monitoring site at Lake Pocasse.

7.2.2 EXISTING WATER QUALITY CONDITIONS

7.2.2.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 418 summarizes the water quality conditions that were monitored in Lake Pocasse at the near-dam, deepwater ambient monitoring site (i.e., site POCLKND1) during 2009. A review of these results indicated no exceedances of water quality standards. However, it is noted that the monitored phosphorus levels (i.e., total, dissolved, and ortho-) were extremely high (Plate 418).

7.2.2.2 Summer Thermal Stratification

Existing summer thermal stratification was assessed for Lake Pocasse, based on monitoring results obtained at the near-dam, deepwater ambient monitoring site (i.e., site POCDLKND1) during 2009. Temperature depth profiles were constructed from water quality data collected during the summer months (Plate 419). The shallow depth (i.e., < 5 meters) inhibited a significant temperature-depth gradient from forming in Lake Pocasse in the near-dam lacustrine area during the summer (Plate 419).

7.2.2.3 Summer Dissolved Oxygen Conditions

Existing summer dissolved oxygen conditions were assessed for Lake Pocasse based on monitoring results obtained at the near-dam, deepwater ambient monitoring site during 2009. Dissolved oxygen depth profiles were constructed from water quality data collected during the summer months (Plate 420). The measured summer dissolved oxygen-depth profiles exhibited no significant variability with depth (Plate 420).

7.2.2.4 Lake Trophic Status

Trophic State Index (TSI) values for Lake Pocasse were calculated from monitoring data collected during 2009 at the near-dam, ambient monitoring site (i.e., site POCLKND1). Table 7-2 summaries the TSI values calculated for the lake. The TSI values indicate that the near-dam lacustrine area of Lake Audubon is in an extremely hypereutrophic state.

Table 7-2. Summary of Trophic State Index (TSI) values calculated for Lake Pocasse for 2009.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	4	67	68	62	72
TSI(TP)	4	89	89	87	91
TSI(Chl)	4	78	81	64	86
TSI(Avg)	4	78	80	71	82

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values irregardless of the parameters available to calculate the average.

Note: See Section 4.1.4 for discussion of TSI calculation.

7.2.2.5 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota's impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored in Lake Pocasse during 2009 do not indicate impairment due to exceedances of conventional or toxic parameters. However, the extreme hypereutrophic conditions monitored in the lake support South Dakota's listing of Lake Pocasse as impaired due to eutrophication.

7.3 LAKE YANKTON

7.3.1 BACKGROUND INFORMATION

7.3.1.1 Lake Description

Lake Yankton is an "oxbow" lake of the Missouri River that straddles the Nebraska and South Dakota border, just downstream of Gavins Point Dam. The lake was formed when the Gavins Point Dam embankment and the training dike downstream of the dam's outlet were constructed and cutoff a portion of the Missouri River channel. Lake Yankton has a surface area of approximately 250 acres.

7.3.1.2 Water Quality Standards and Section 303(d) Listings

Pursuant to the Federal Clean Water Act, the State of South Dakota has designated the following water quality-dependent beneficial uses for Lake Yankton: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, fish and wildlife propagation, and stock watering. The State of Nebraska has designated the following beneficial uses to Lake Yankton: primary contact recreation, Class I warmwater aquatic life, agricultural water supply, and aesthetics. The uses designated by the States of South Dakota and Nebraska to Lake Yankton are consistent with each other. Neither of the two States has placed Lake Yankton on the State's Section 303(d) list of impaired waters, or has issued fish consumption advisories for the lake.

7.3.1.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Lake Yankton since 1982. Figure 7-3 shows the locations at Lake Yankton that have been monitored for water quality. The deepwater site (YAKLKND1) was monitored monthly (May - September) in 2006 and 2009. The bacteria site (YAKBACT1) was monitored weekly (May - September) during the 5-year period 2005 through 2009.

7.3.2 EXISTING WATER QUALITY CONDITIONS

7.3.2.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 421 summarizes the water quality conditions that were monitored in Lake Yankton at the deepwater ambient monitoring site (i.e., site YAKLKND1) during 2006 and 2009. Based on the criteria for the protection of warmwater aquatic life, 38% of the observations did not meet the dissolved oxygen criterion. The dissolved oxygen measurements that were below the 5.0 mg/l criterion occurred near the lake bottom in the hypolimnion during the summer on occasions when the lake was thermally stratified. Nebraska's dissolved oxygen criteria are not applicable to the hypolimnion when lakes are thermally stratified. The pesticides atrazine and chlorpyrifos were detected on one occasion at levels above State water quality standards criteria.

7.3.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification was assessed for Lake Yankton, based on monitoring results obtained at the deepwater ambient monitoring site (i.e., site YAKLKND1) during 2006 and 2009. Temperature depth profiles were constructed from water quality data collected during the summer months (Plate 422). Summer thermal stratification appears to be present in Lake Yankton, with water temperatures near the lake bottom being up to 10°C cooler then at the lake surface (Plate 422). The cooler water temperatures near the lake bottom are attributed to groundwater inflow to the lake from "relief wells" along Gavins Point Dam.

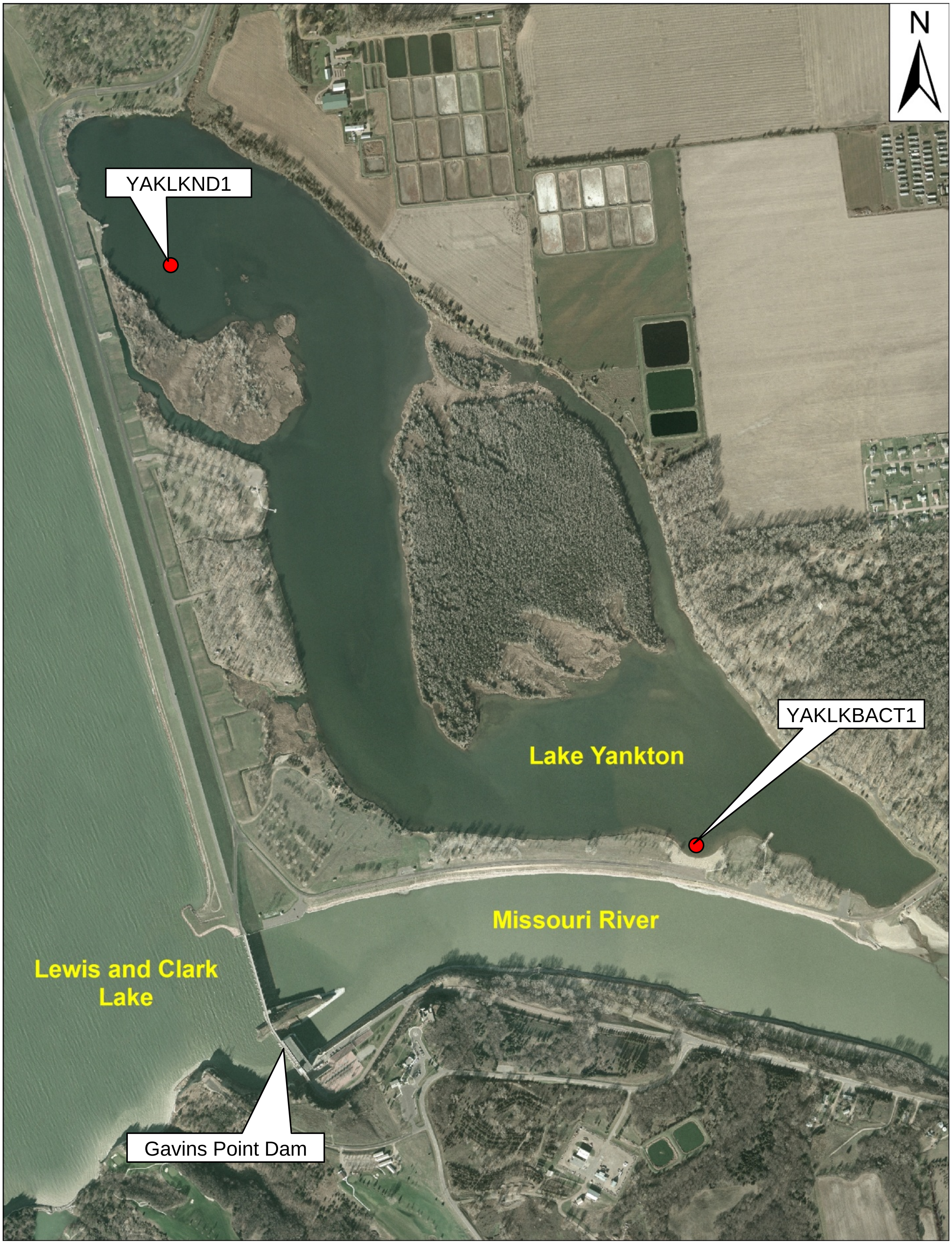

Figure 7-3. Location of water quality monitoring sites on Lake Yankton.

7.3.2.3 Near-Dam Dissolved Oxygen Depth Profile Plots

Existing summer dissolved oxygen conditions were assessed for Lake Yankton based on monitoring results obtained at the deepwater ambient monitoring site during 2006 and 2009. Dissolved oxygen depth profiles were constructed from water quality data collected during the months of June, July, August, and September (Plate 423). The measured summer dissolved oxygen-depth profiles exhibited extreme variability with depth. Dissolved oxygen concentrations consistently fell below 1 mg/l in the bottom 1 to 2 meters of the lake (Plate 423). The lowest dissolved oxygen concentration measured was 0.2 mg/l.

7.3.2.4 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Lake Yankton during the summer in 2006 and 2009 were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 1-meter of the reservoir bottom. The compared samples were collected at site YAKLKND1. During the period a total of 4 to 8 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total ammonia, total phosphorus, total iron, and total manganese (Plate 424). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for water temperature, dissolved oxygen, ORP, pH, alkalinity, and total iron. Parameters that were significantly lower in the near-bottom water of Lake Yankton included: water temperature ($p < 0.01$), dissolved oxygen ($p < 0.001$), ORP ($p < 0.05$), and pH ($p < 0.001$). Parameters that were significantly higher in the near-bottom water included: alkalinity ($p < 0.05$) and total iron ($p < 0.05$). Small sample size and high variability limited significance testing for total ammonia and total manganese. The box plots of these parameters show observable differences between surface and bottom conditions (Plate 424).

7.3.2.5 Lake Trophic Status

Trophic State Index (TSI) values for Lake Yankton were calculated from monitoring data collected during the 2006 and 2009 at the deepwater ambient monitoring site (i.e., site YAKLKND1). Table 7-3 summaries the TSI values calculated for the lake. The TSI values indicate that the Lake Yankton is in a eutrophic state.

Table 7-3. Summary of Trophic State Index (TSI) values calculated for Lake Yankton for 2006 and 2009.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	10	60	58	52	77
TSI(TP)	10	53	50	41	72
TSI(Chl)	10	58	57	40	79
TSI(Avg)	10	57	58	48	63

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values the parameters available to calculate the average.

Note: See Section 4.1.4 for discussion of TSI calculation.

7.3.2.6 Bacteria Monitoring at the Training Dike Swimming Beach at Lake Yankton

During the 5-year period 2005 through 2009, bacteria samples were collected weekly from May through September at the Training Dike swimming beach located on Lake Yankton. Table 7-4 summarizes the results of the bacteria sampling. The geometric means were calculated as running geometric means for five consecutive weekly bacteria samples and nondetects were set to 1. The bacteria sampling results were compared to following bacteria criteria for support of "full-body contact" recreation:

Fecal Coliform:

Bacteria of the fecal coliform group should not exceed a geometric mean of 200/100ml, nor equal or exceed 400/100ml, in more than 10% of the samples. These criteria are based on a minimum of five samples taken within a 30-day period.

E. coli:

E. coli bacteria should not exceed a geometric mean of 126/100ml. For increased confidence of the criteria, the geometric mean should be based on a minimum of five samples taken within a 30-day period. Single sample maximum allowable density for designated bathing beaches is 235/100ml.

Based on these criteria and Nebraska's impairment assessment methodology (Section 4.1.6.2), "full-body contact" recreation was fully supported at the Training Dike swimming beach on Lake Yankton during the May through September recreational season during the 5-year period of 2005 through 2009.

Table 7-4. Summary of weekly (May through September) bacteria sampling conducted at the Training Dike swimming beach on Lake Yankton during the 5-year period 2005 through 2009.

	Fecal Coliform Bacteria	***E. coli* Bacteria**
Number of Samples	105	105
Mean	17	14
Median	4	2
Minimum	n.d.	n.d.
Maximum	200	357
Percent of Fecal Coliform samples exceeding 400/100ml	0%	-----
Percent of *E. coli* samples exceeding 235/100ml	-----	1%
• **Geometric Mean**		
Number of Geomeans	86	86
Average	8	6
Median	6	4
Minimum	2	1
Maximum	47	37
Number of Fecal Coliform geomeans exceeding 200/100ml	0	-----
Number of *E. coli* geomeans exceeding 126/100ml	-----	0

n.d. = Not detected.
Note: Not detected values set to 1 to calculate mean and geometric mean.

7.3.2.7 Impairment of Designated Water Quality Beneficial Uses

Based on the State of Nebraska's impairment assessment methodology (Section 4.1.6.2), the water quality conditions monitored in Lake Yankton during 2006 and 2009 do not indicate impairment of any designated water quality dependent beneficial uses.

7.3.3 WATER QUALITY TRENDS (1980 THROUGH 2009)

Water quality trends over the period of 1982 through 2009 were determined for Lake Yankton for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the lake during the months of May through October at the deepwater site (i.e., site YAKLKND1). Plate 425 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Lake Yankton exhibited significant trends for Secchi depth (decreasing) and TSI (increasing) (Plate 425). No significant trends were detected for total phosphorus and chlorophyll *a* (Plate 425). Over the 25-year period, the lake has generally moved from a moderately eutrophic to a eutrophic state (Plate 425).

8 WATER QUALITY MONITORING AND MANAGEMENT ACTIVITIES PLANNED FOR FUTURE YEARS

8.1 WATER QUALITY DATA COLLECTION

A tentative schedule of water quality monitoring targeted for implementation over the next 5 years is given in Table 8-1. The identified data collection activities are considered the minimum needed to allow for the annual assessment of water quality conditions at District projects and the preparation of project-specific water quality reports and water quality management objectives for the Mainstem System Projects. The actual monitoring activities that are implemented will be dependent upon the availability of future resources.

8.2 PROJECT-SPECIFIC WATER QUALITY MANAGEMENT PLANNING

Corps guidance for water quality and environmental management at civil works projects (USACE, 1995) identifies the need to develop specific water quality management objectives for each project and to outline procedures to be implemented to meet those objectives. The identified objectives and procedures are to be included in the project water control plans. The water quality management objectives are to be reviewed and updated as needed, but at least every 10 years.

The Omaha District's intent is to develop water quality management objectives for Mainstem System project based on the findings presented in project-specific water quality reports. Therefore, it is important that the project-specific report for a project be updated prior to the development or update of the water quality management objectives for the project. This will ensure that the water quality management objectives for the projects address all of the known surface water quality issues and concerns. Where data are lacking or water quality issues need to be further evaluated, monitoring should be implemented to address these data needs prior to the preparation of the project-specific water quality report. Water quality management objectives will be developed in coordination with project operations staff and, as appropriate, the Northwestern Division's Missouri River Basin Water management Division (MRBWMD). The project water quality management objectives will be provided to the District's Engineering and Operation Divisions and the MRBWMD for incorporation into Project Water Control Manuals and Master Plans.

The CE-QUAL-W2 hydrodynamic and water quality model is being applied to facilitate the development of project-specific water quality reports and project-specific water quality management objectives. The tentative schedule for implementing these water-quality management planning activities on the Mainstem System projects is given in Table 8-2.

8.3 TOTAL MAXIMUM DAILY LOADS (TMDLS)

The District will participate, as appropriate, as a stakeholder in the development and implementation of TMDLs on waterbodies that involve District projects.

Table 8-1. Water quality monitoring planned by the District at Missouri River Mainstem System Projects for the next 5 years and the intended data collection approach. Actual monitoring activities implemented will be dependent upon available resources.

Mainstem Project Areas to be Monitored	**Long-Term Fixed Station Monitoring**	**Intensive Surveys**	**Special Studies**	**Investigative Monitoring**
• Fort Peck		*	X[c]	X[e]
- Fort Peck Lake (3 Sites: Near-dam, Hell Creek, and Rock Creek)	X[a]			
- Missouri River Inflow to Fort Peck Lake (near Landusky, MT)	X[a]			
- Fort Peck Powerplant (“Raw-Water” Supply Line)	X[a]			
• Garrison		*	X[d]	X[e]
- Lake Sakakawea (5 Sites: Near-dam, Beulah Bay, Deepwater Bay, New Town, White Tail Bay)	X[a]			
- Missouri River Inflow to Lake Sakakawea (near Williston, ND)	X[a]			
- Garrison Powerplant (“Raw-Water” Supply Line)	X[a]			
- Lake Audubon	2012, 2015			
• Oahe		*		X[e]
- Lake Oahe (5 Sites: Near-dam, Cheyenne River Area, Whitlocks Bay, Mobridge, Beaver Creek)	X[a]			
- Missouri River Inflow to Lake Oahe (near Bismarck, ND)	X[a]			
- Oahe Powerplant (“Raw-Water” Supply Line)	X[a]			
- Lake Pocasse	2012, 2015			
• Big Bend				
- Lake Sharpe (1 Site: Near-dam)	X[a]			
- Lake Sharpe (2 Sites: Fort George, Iron Nation		2008-2010		
- Bad River Inflow to Lake Sharpe (at Fort Pierre, SD)		2008-2010		
- Big Bend Powerplant (“Raw-Water” Supply Line)	X[a]			
• Fort Randall		*		X[e]
- Lake Francis Case (1 Site: Near-dam)	X[a]			
- Fort Randall Powerplant (“Raw-Water” Supply Line)	X[a]			
• Gavins Point	X[a]			X[e]
- Lewis and Clark Lake (1 Site: Near-dam)	X[a]			
- Lewis and Clark Lake (4 Sites: Weigand, Bloomfield, Devils Nest, and Charley Creek)		2008-2010		
- Missouri River Inflow to Lewis and Clark Lake (near Niobrara, NE)		2008-2010		
- Niobrara River Inflow to Missouri River (near Niobrara, NE)		2008-2010		
- Gavins Point Powerplant (“Raw-Water” Supply Line)	X[a]			
- Lake Yankton	2012, 2015			
• Missouri River – Fort Randall Dam to Lewis and Clark Lake (3 Sites: Fort Randall Dam Tailwaters, RM851, and RM841)	X[b]			X[e]
• Missouri River – Gavins Point Dam to Rulo, Nebraska (7 Sites: Gavins Point Tailwaters, RM774, RM753, RM691, RM619, RM563, and RM498).	X[b]	2010-2012[f]		X[e]

* A 3-year intensive survey was completed at Garrison in 2005, Fort Peck in 2006, Oahe in 2007, and Fort Randall in 2008.

[a] To be monitored every year.

[b] Six sites (RM851, RM774, RM691, RM619, RM563, and RM498) are being monitored under an Interagency Support Agreement with the Nebraska Department of Environmental Quality.

[c] Special Study will be implemented, as necessary, to facilitate application of a Scoping Study to evaluate the feasibility of constructing a “multi-level” intake structure at Fort Peck Dam to allow better management of the water temperature of water discharged through the Fort Peck powerplant.

[d] Special Study will be implemented, as necessary, to facilitate application of short-term water quality measures at Garrison Dam for the management of coldwater fishery habitat in Lake Sakakawea.

[e] Investigative Monitoring will be conducted as necessary and appropriate.

[f] A joint intensive water quality survey is being implemented with the Kansas City District to monitoring water quality along the Missouri River from Gavins Point Dam to the river’s mouth at St. Louis, MO.

Table 8-2. Tentative schedule for water quality management planning activities for the Mainstem System Projects.

Planning Activity	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point	Missouri River*
Ambient water quality monitoring	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
Conduct 3-year intensive water quality survey	Completed (2006)	Completed (2005)	Completed (2007)	2008-10	Completed (2008)	2008-10	2010-12
Prepare Water Quality Special Study Report (Findings of the 3-year intensive water quality survey)	Completed (2007)	Completed (2006)	Completed (2008)	2011	Completed (2009)	2011	2013
Application of CE-QUAL-W2 hydrodynamic and water quality model	2009	Completed (2008) Currently being Updated	2010/2011	2015	2011/12	2014	2012/2013
Prepare Water Quality Special Study Report (Application of the CE-QUAL-W2 Model)	2009	2008 (Updated Report) (2010)	2011	2015	2012	2014	2013
Prepare Project-Specific Water Quality Report	2012	2011	2013	2017	2014	2016	2015
Develop project-specific water quality management objectives	2012	2011	2013	2017	2014	2016	2015

* Downstream of Gavins Point Dam.

9 REFERENCES

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10 PLATES

Plate 1. Summary of monthly (May through September) water quality conditions monitored in Fort Peck Lake near Fort Peck Dam (Site FTPLK1772A) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	25	2206.6	2203.6	2198.7	2220.5	-----	-----	-----
Water Temperature (°C)	0.1	1,291	12.5	12.0	4.0	25.5	26.7[1,2]	0	0%
Dissolved Oxygen (mg/l)	0.1	1,291	8.9	8.8	5.2	12.2	5.0[1,3]	0	0%
Dissolved Oxygen (% Sat.)	0.1	1,247	85.8	89.9	49.9	107.4	-----	-----	-----
Specific Conductance (umho/cm)	1	1,247	525	535	466	556	-----	-----	-----
pH (S.U.)	0.1	1,247	8.2	8.2	7.4	8.8	6.5[1,3], 9.0[1,2]	0	0%
Turbidity (NTUs)	1	1,196	-----	1	n.d.	33	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	1,247	355	343	266	526	-----	-----	-----
Secchi Depth (in.)	1	25	128	125	56	216	-----	-----	-----
Alkalinity, Total (mg/l)	7	52	154	152	140	180	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	50	2.3	2.4	n.d.	3.8	-----	-----	-----
Chemical Oxygen Demand, Total (mg/l)	2	44	7	7	n.d.	17	-----	-----	-----
Chloride (mg/l)	1	42	9	9	7	10	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Measured	1	687	5	3	n.d.	20	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	27	-----	2	n.d.	10	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	50	358	350	260	478	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	54	-----	0.02	n.d.	0.58	3.8 [1,2,4], 1.7[1,4,5]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	54	0.4	0.3	n.d.	1.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	54	-----	n.d.	n.d.	0.15	-----	-----	-----
Nitrogen, Total (mg/l)	0.1	54	0.4	0.3	n.d.	1.4	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	54	-----	0.02	n.d.	0.11	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	54	0.05	0.03	n.d.	0.32	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	54	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	49	119	120	37	130	-----	-----	-----
Suspended Solids, Total (mg/l)	4	54	-----	n.d.	n.d.	14	-----	-----	-----
Microcystin, Total (ug/l)	0.2	24	-----	n.d.	n.d.	0.4	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for B-3 classified waters.
- (2) Daily maximum criterion (monitoring results directly comparable to criterion).
- (3) Daily minimum criterion (monitoring results directly comparable to criterion).
- (4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (5) 30-day average criterion (monitoring results not directly comparable to criterion).

Plate 2. Summary of monthly (June through September) water quality conditions monitored in Fort Peck Lake near Skunk Coulee Bay (site FTPLK1778DW) during the 2-year period 2005 through 2006.

	Monitoring Results[A]						Water Quality Standards Attainment		
Parameter	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	8	2203.4	2203.1	2201.8	2206.2	-----	-----	-----
Water Temperature (°C)	0.1	314	15.2	14.6	8.5	26.3	26.7[1,2]	0	0%
Dissolved Oxygen (mg/l)	0.1	314	8.4	8.4	5.7	10.0	5.0[1,3]	0	0%
Dissolved Oxygen (% Sat.)	0.1	314	86.7	90.9	57.1	106.5	-----	-----	-----
Specific Conductance (umho/cm)	1	314	510	501	466	545	-----	-----	-----
pH (S.U.)	0.1	314	8.3	8.4	7.6	8.7	6.5[1,3], 9.0[1,2]	0	0%
Turbidity (NTUs)	1	314	-----	2	n.d.	28	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	314	388	372	284	534	-----	-----	-----
Secchi Depth (in)	1	8	143	123	102	250	-----	-----	-----

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.
(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.
(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).
(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
(1) Criteria for B-3 classified waters.
(2) Daily maximum criterion (monitoring results directly comparable to criterion).
(3) Daily minimum criterion (monitoring results directly comparable to criterion).

Plate 3. Summary of monthly (June through September) water quality conditions monitored in Fort Peck Lake near The Pines Recreation Area (site FTPLK1789DW) during the 2-year period 2005 through 2006.

	Monitoring Results[A]						Water Quality Standards Attainment		
Parameter	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	8	2203.5	2203.1	2201.8	2206.2	-----	-----	-----
Water Temperature (°C)	0.1	277	15.6	15.0	8.9	24.4	26.7[1,2]	0	0%
Dissolved Oxygen (mg/l)	0.1	277	8.0	8.3	2.2	9.7	5.0[1,3]	1	<1%
Dissolved Oxygen (% Sat.)	0.1	277	84.2	90.1	20.7	102.4	-----	-----	-----
Specific Conductance (umho/cm)	1	277	506	497	459	559	-----	-----	-----
pH (S.U.)	0.1	277	8.3	8.3	6.9	8.8	6.5[1,3], 9.0[1,2]	0	0%
Turbidity (NTUs)	1	276	7	3	n.d.	40	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	277	378	342	136	528	-----	-----	-----
Secchi Depth (in)	1	8	113	108	78	148	-----	-----	-----
Alkalinity, Total (mg/l)	7	19	155	160	140	170	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	19	2.4	2.4	2.2	2.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	8	7	6	4	12	-----	-----	-----
Chloride (mg/l)	1	8	8	8	7	8	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	8	-----	1	n.d.	4	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	19	343	350	300	360	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	19	-----	0.02	n.d.	0.07	3.1 [1,2,4], 1.4[1,4,5]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	19	0.2	0.3	0.2	0.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	19	-----	n.d.	n.d.	0.57	-----	-----	-----
Nitrogen, Total (mg/l)	0.1	19	0.3	0.3	0.2	0.9	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	19	-----	n.d.	n.d.	0.05	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	19	0.05	0.04	n.d.	0.23	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	19	-----	n.d.	n.d.	0.05	-----	-----	-----
Sulfate (mg/l)	1	19	119	120	110	130	-----	-----	-----
Suspended Solids, Total (mg/l)	4	19	-----	n.d.	n.d.	8	-----	-----	-----
Microcystin (ug/l)	0.2	7	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.
(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.
(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.
(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).
(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
(1) Criteria for B-3 classified waters.
(2) Daily maximum criterion (monitoring results directly comparable to criterion).
(3) Daily minimum criterion (monitoring results directly comparable to criterion).
(4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(5) 30-day average criterion (monitoring results not directly comparable to criterion).

Plate 4. Summary of monthly (June through September) water quality conditions monitored in Fort Peck Lake near Hell Creek Bay (site FTPLK1805DW) during the 5-year period 2005 through 2009.

	Monitoring Results[A]						Water Quality Standards Attainment		
Parameter	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	19	2206.9	2203.1	2198.7	2220.5	-----	-----	-----
Water Temperature (°C)	0.1	478	16.0	16.7	5.5	27.4	26.7[1,2]	1	<1%
Dissolved Oxygen (mg/l)	0.1	478	8.1	8.4	3.5	12.1	5.0[1,3]	32	7%
Dissolved Oxygen (% Sat.)	0.1	458	84.1	89.1	35.3	111.6	-----	-----	-----
Specific Conductance (umho/cm)	1	458	512	520	418	565	-----	-----	-----
pH (S.U.)	0.1	458	8.3	8.4	7.1	9.0	6.5[1,3], 9.0[1,2]	0	0%
Turbidity (NTUs)	1	434	-----	3	n.d.	31	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	458	342	323	263	508	-----	-----	-----
Secchi Depth (in)	1	19	94	84	46	150	-----	-----	-----
Alkalinity, Total (mg/l)	7	40	151	149	140	170	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	38	2.5	2.6	n.d.	4.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	30	7	8	n.d.	18	-----	-----	-----
Chloride (mg/l)	1	30	8	8	4	10	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Measured	1	264	6	5	n.d.	26	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	19	4	3	n.d.	18	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	40	344	345	294	452	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	40	-----	0.03	n.d.	0.14	3.9 [1,2,4], 1.7[1,4,5]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	40	0.4	0.3	n.d.	1.1	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	40	-----	n.d.	n.d.	0.15	-----	-----	-----
Nitrogen, Total (mg/l)	0.1	40	0.4	0.3	n.d.	1.1			
Phosphorus, Dissolved (mg/l)	0.02	40	-----	0.02	n.d.	0.24			
Phosphorus, Total (mg/l)	0.02	40	0.04	0.02	n.d.	0.34	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	40	-----	n.d.	n.d.	0.23	-----	-----	-----
Sulfate (mg/l)	1	40	116	120	85	140	-----	-----	-----
Suspended Solids, Total (mg/l)	4	40	-----	n.d.	n.d.	8	-----	-----	-----
Microcystin (ug/l)	0.2	17	-----	n.d.	n.d.	0.3	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for B-3 classified waters.

(2) Daily maximum criterion (monitoring results directly comparable to criterion).

(3) Daily minimum criterion (monitoring results directly comparable to criterion).

(4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(5) 30-day average criterion (monitoring results not directly comparable to criterion).

Plate 5. Summary of monthly (June through September) water quality conditions monitored in Fort Peck Lake in the Big Dry Creek Arm of the reservoir (site FTPLKBDCA01) during the 2-year period 2005 through 2006.

	Monitoring Results[A]						Water Quality Standards Attainment		
Parameter	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	8	2203.4	2203.1	2201.8	2206.2	-----	-----	-----
Water Temperature (°C)	0.1	315	15.4	14.5	8.7	25.4	26.7[1,2]	0	0%
Dissolved Oxygen (mg/l)	0.1	315	8.4	8.3	5.7	10.0	5.0[1,3]	0	0%
Dissolved Oxygen (% Sat.)	0.1	315	87.2	91.3	56.8	110.6	-----	-----	-----
Specific Conductance (umho/cm)	1	315	514	504	350	550	-----	-----	-----
pH (S.U.)	0.1	315	8.3	8.3	7.8	8.8	6.5[1,3], 9.0[1,2]	0	0%
Turbidity (NTUs)	1	315	-----	2	n.d.	31	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	315	389	354	301	507	-----	-----	-----
Secchi Depth (in)	1	8	138	129	76	240	-----	-----	-----

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for B-3 classified waters.

(2) Daily maximum criterion (monitoring results directly comparable to criterion).

(3) Daily minimum criterion (monitoring results directly comparable to criterion).

Plate 6. Summary of monthly (June through September) water quality conditions monitored in Fort Peck Lake near Rock Creek Bay (site FTPLKBDCA02) during the 5-year period 2005 through 2009.

	Monitoring Results[A]						Water Quality Standards Attainment		
Parameter	**Detection Limit[B]**	**No. of Obs.**	**Mean[C]**	**Median**	**Min.**	**Max.**	**State WQS Criteria[D]**	**No. of WQS Exceedances**	**Percent WQS Exceedance**
Pool Elevation (ft-msl)	0.1	22	2207.3	2203.7	2198.7	2220.5	-----	-----	-----
Water Temperature (°C)	0.1	405	16.9	17.8	5.2	24.2	26.7[1,2]	0	0%
Dissolved Oxygen (mg/l)	0.1	405	8.7	8.5	5.6	11.7	5.0[1,3]	0	0%
Dissolved Oxygen (% Sat.)	0.1	391	93.0	94.8	59.9	105.3	-----	-----	-----
Specific Conductance (umho/cm)	1	391	538	544	491	580	-----	-----	-----
pH (S.U.)	0.1	391	8.4	8.5	7.8	8.9	6.5[1,3], 9.0[1,2]	0	0%
Turbidity (NTUs)	1	388	-----	2	n.d.	25	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	391	342	323	260	492	-----	-----	-----
Secchi Depth (in)	1	22	113	108	54	198	-----	-----	-----
Alkalinity, Total (mg/l)	7	29	153	151	140	170	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	28	2.5	2.5	n.d.	4.0	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	22	8	9	n.d.	15	-----	-----	-----
Chloride (mg/l)	1	22	9	9	7	10	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Measured	1	219	6	3	n.d.	22	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	20	3	2	n.d.	12	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	29	361	360	328	418	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	29	-----	0.02	n.d.	0.14	3.9 [1,2,4], 1.7[1,4,5]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	29	0.4	0.3	n.d.	1.5	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	29	-----	n.d.	n.d.	0.46	-----	-----	-----
Nitrogen, Total (mg/l)	0.1	29	0.4	0.3	0.2	1.5	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	29	-----	n.d.	n.d.	0.06	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	29	-----	0.02	n.d.	0.06	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	29	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	29	129	126	110	180	-----	-----	-----
Suspended Solids, Total (mg/l)	4	29	-----	n.d.	n.d.	5	-----	-----	-----
Microcystin (ug/l)	0.2	19	-----	n.d.	n.d.	0.4	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for B-3 classified waters.
- (2) Daily maximum criterion (monitoring results directly comparable to criterion).
- (3) Daily minimum criterion (monitoring results directly comparable to criterion).
- (4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (5) 30-day average criterion (monitoring results not directly comparable to criterion).

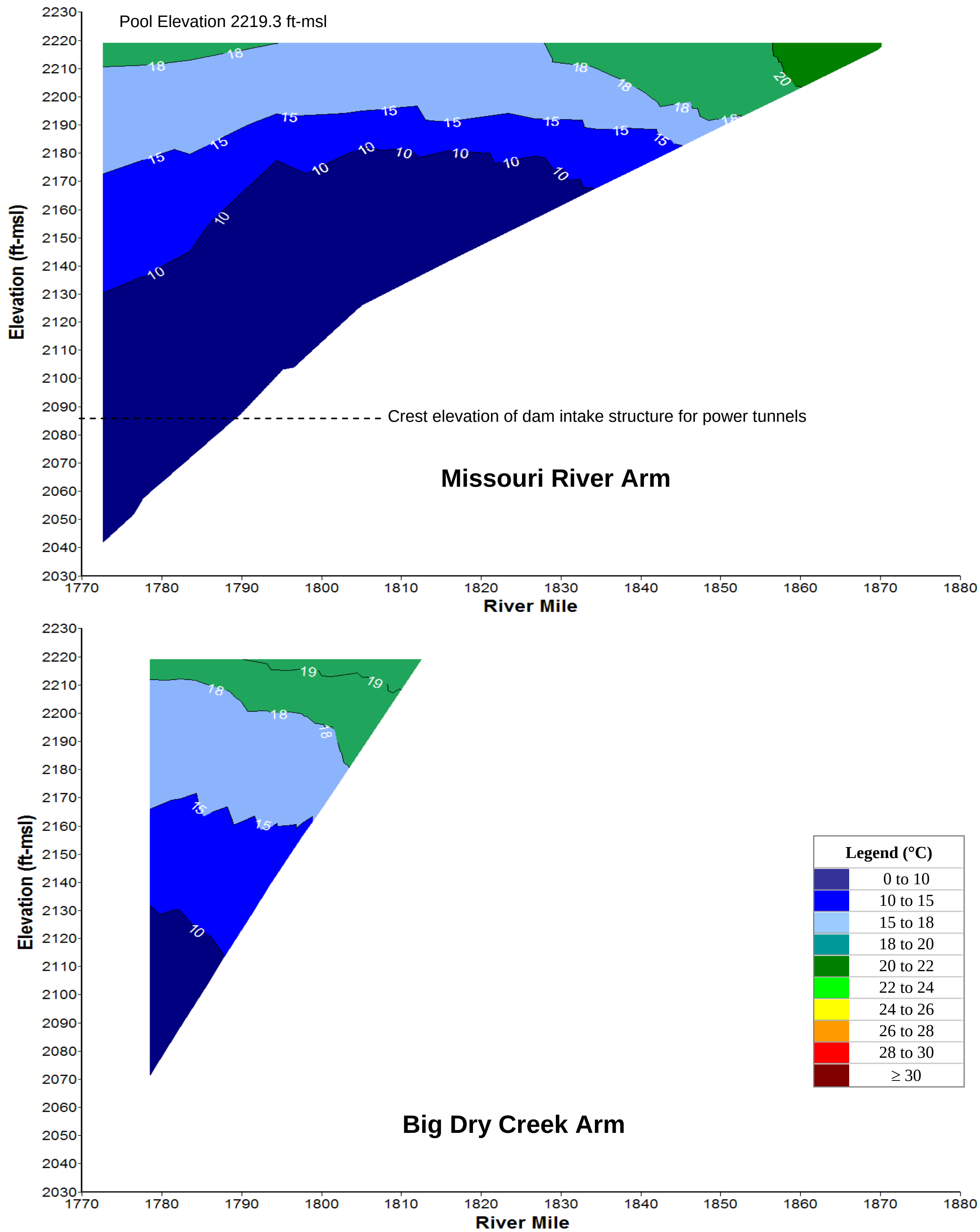


Plate 7. Longitudinal water temperature (°C) contour plot of Fort Peck Lake based on depth-profile water temperatures measured at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on June 20, 2009.

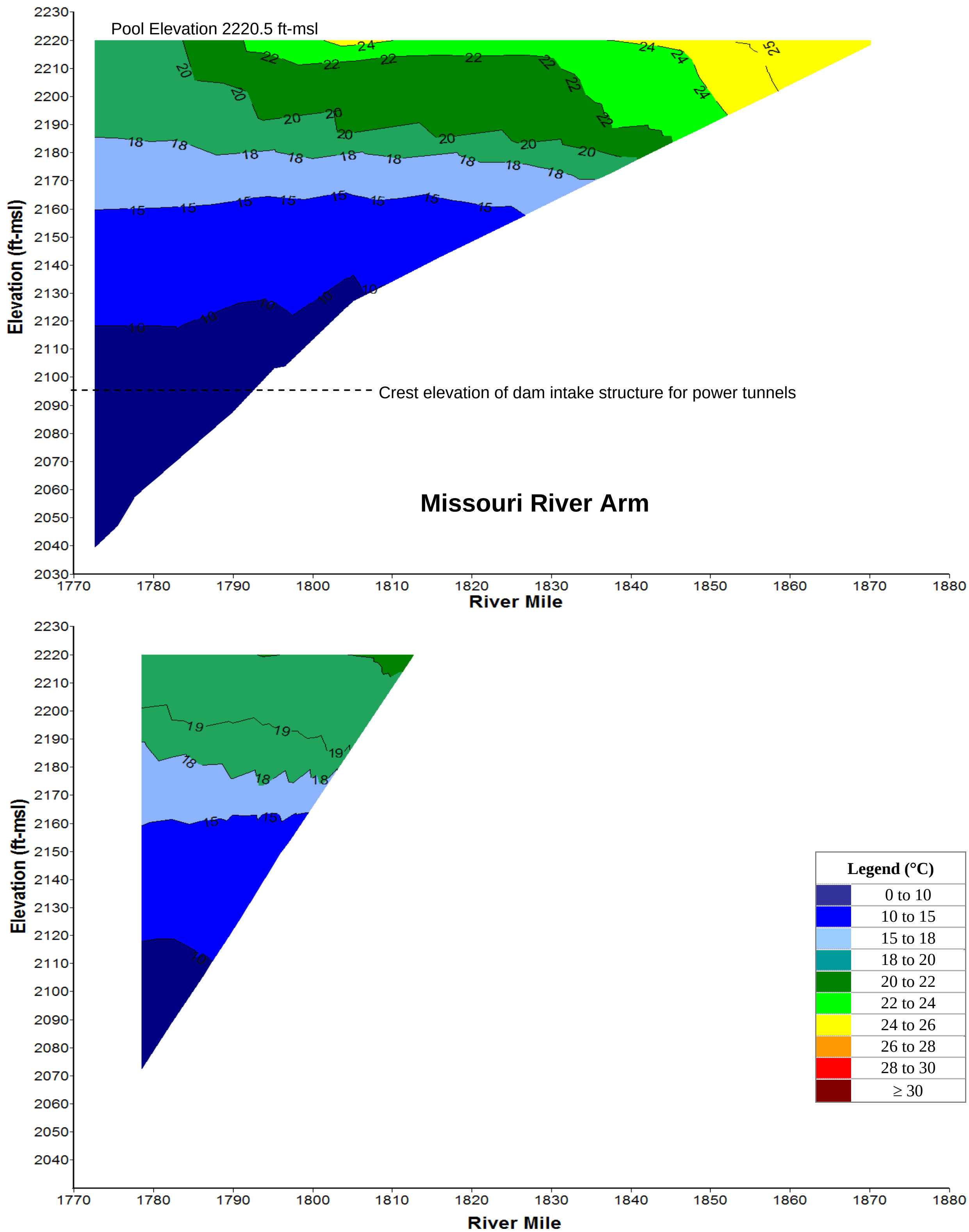


Plate 8. Longitudinal water temperature (°C) contour plot of Fort Peck Lake based on depth-profile water temperatures measured at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on July 18, 2009.

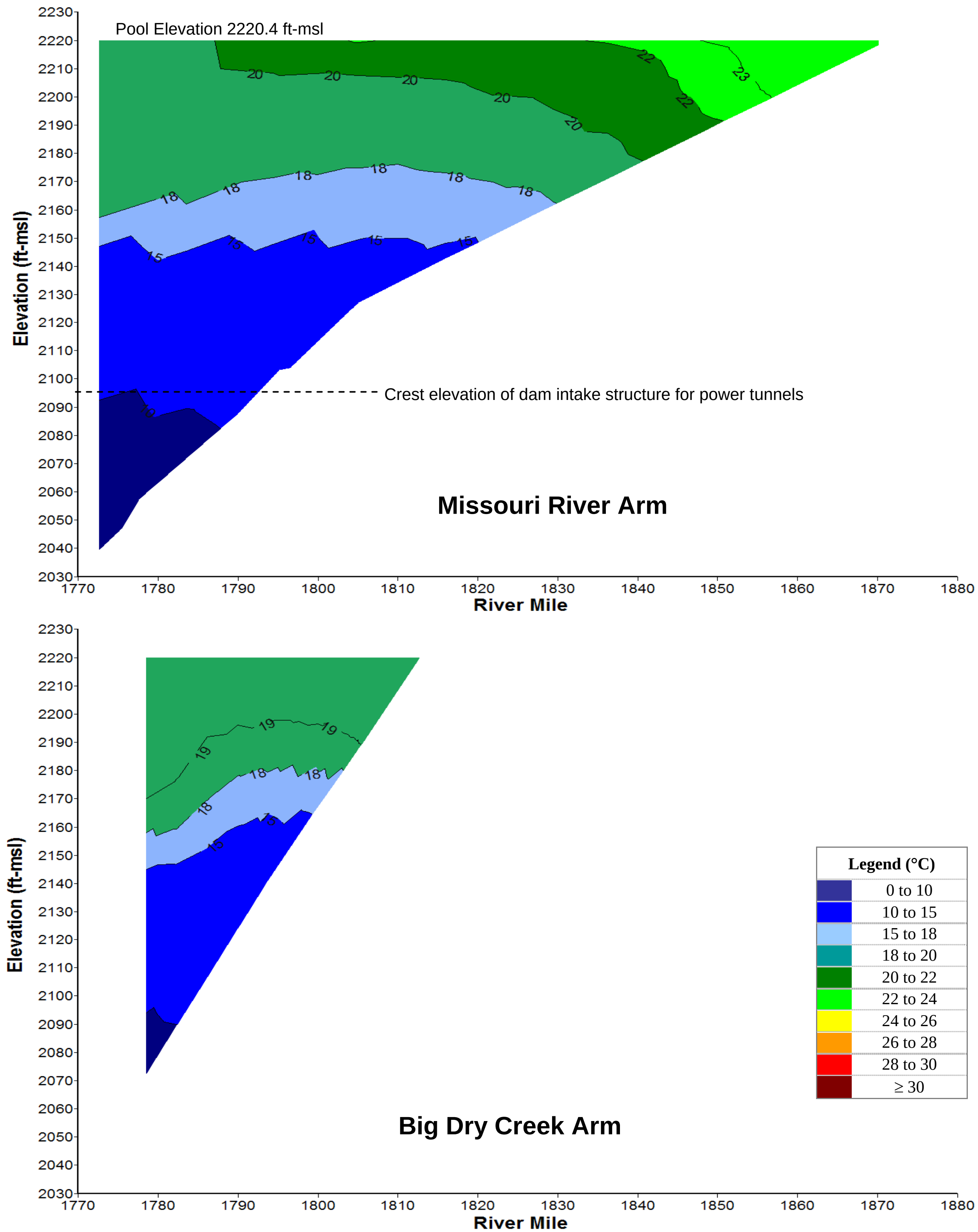


Plate 9. Longitudinal water temperature (°C) contour plot of Fort Peck Lake based on depth-profile water temperatures measured at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on August 22, 2009.

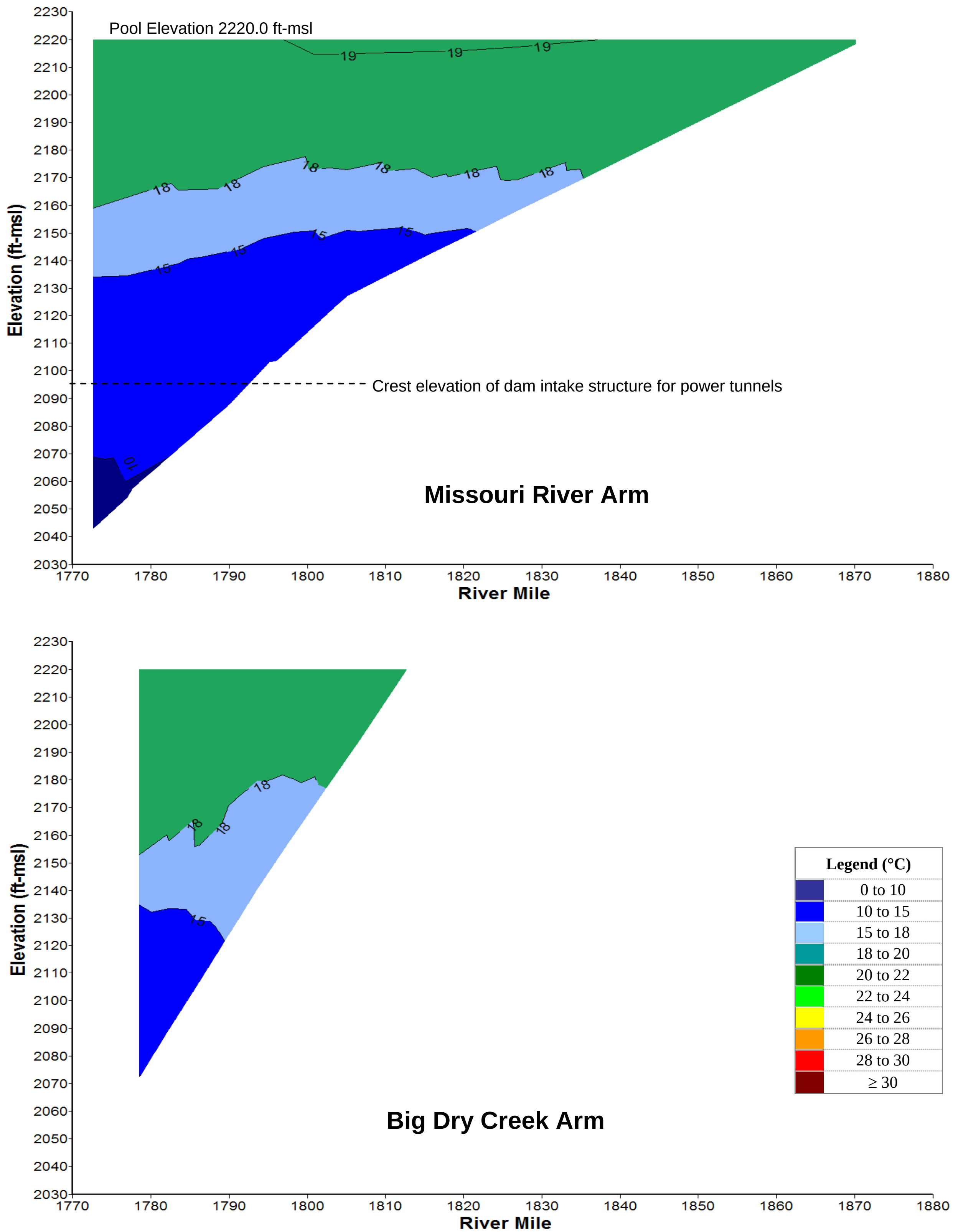


Plate 10. Longitudinal water temperature (°C) contour plot of Fort Peck Lake based on depth-profile water temperatures measured at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on September 20, 2009.

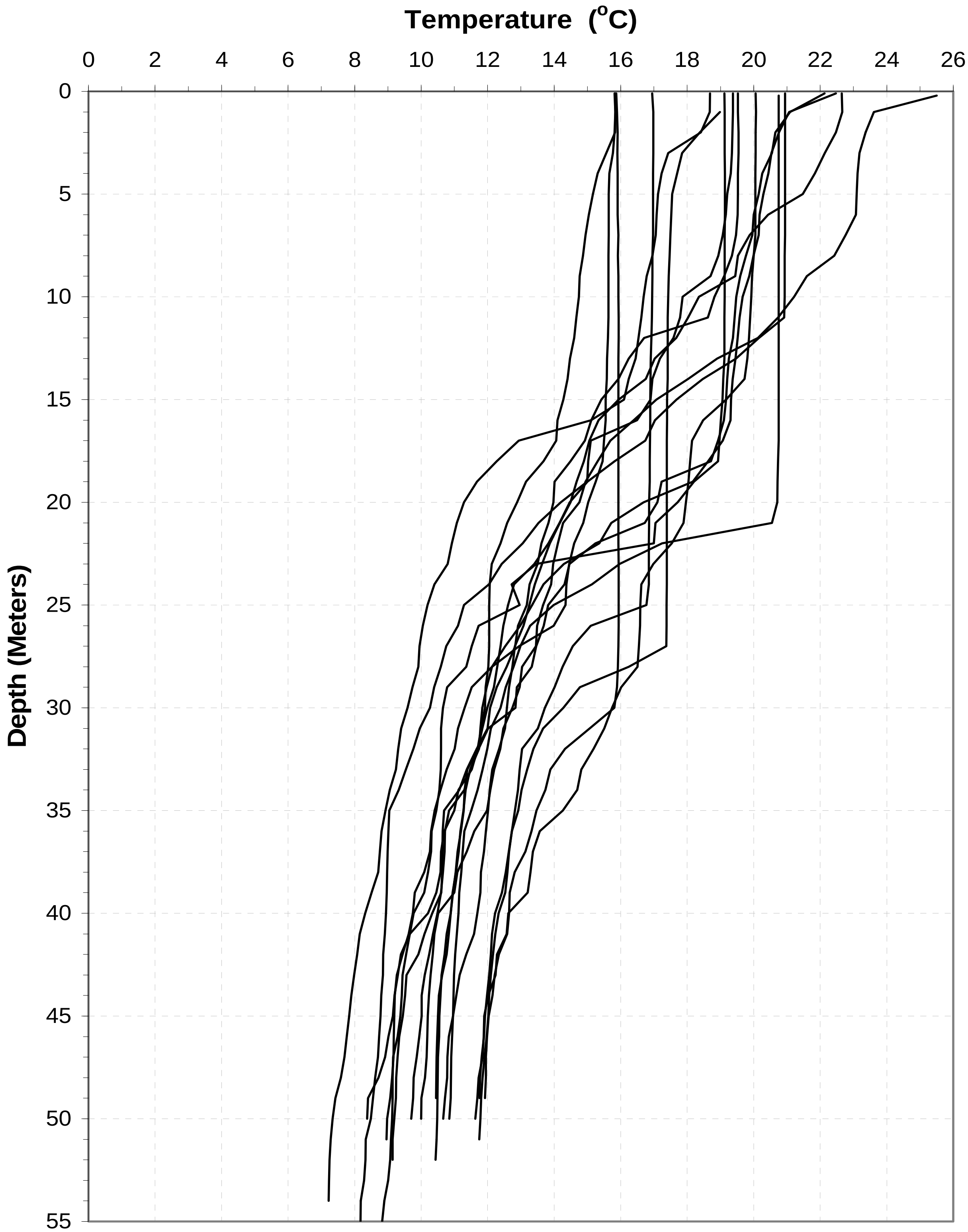


Plate 11. Temperature depth profiles for Fort Peck Lake compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., FTPLK1772A) during the summer over the 5-year period of 2005 to 2009.

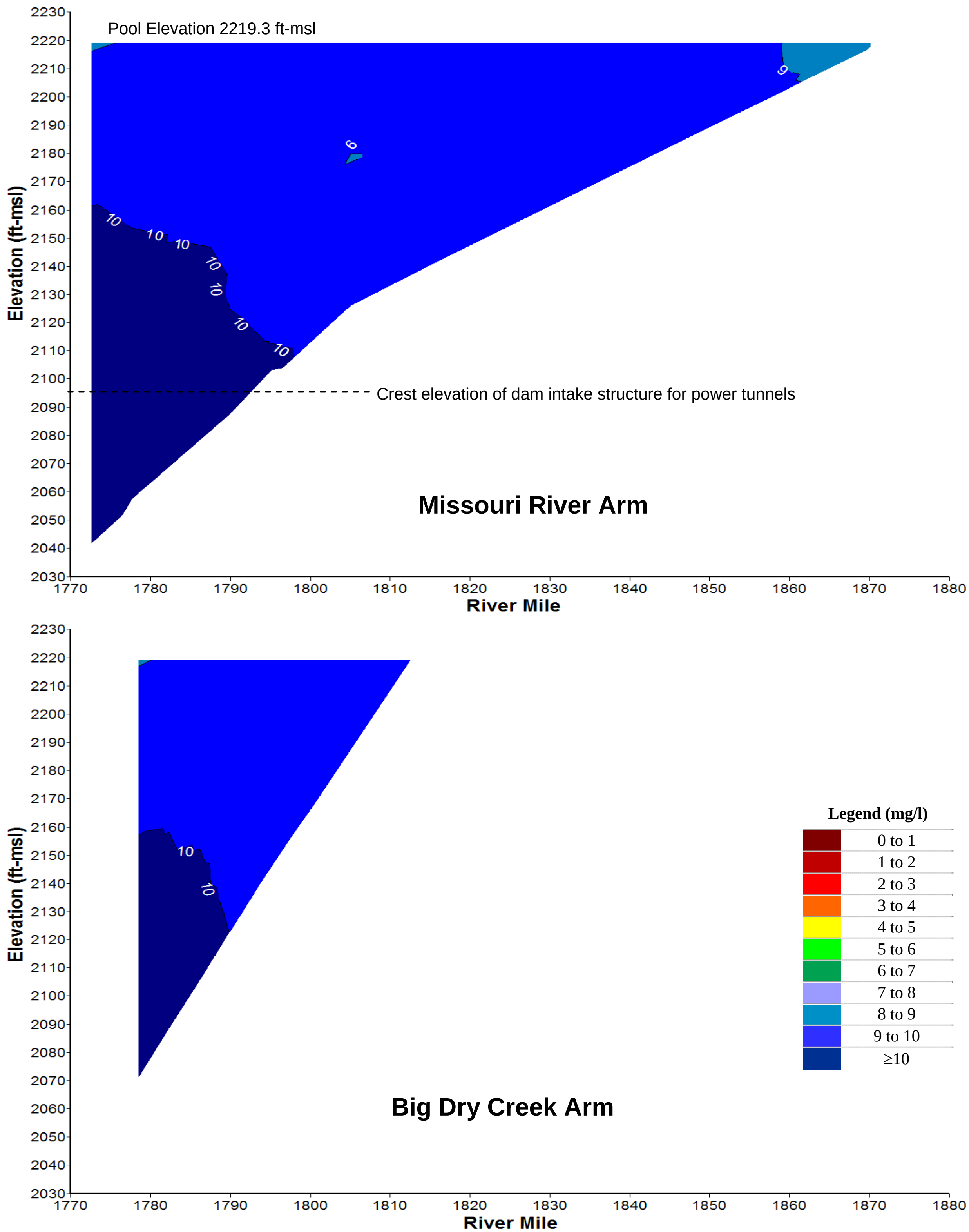


Plate 12. Longitudinal dissolved oxygen (mg/l) contour plot of Fort Peck Lake based on depth-profile dissolved oxygen concentrations monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on June 20, 2009.

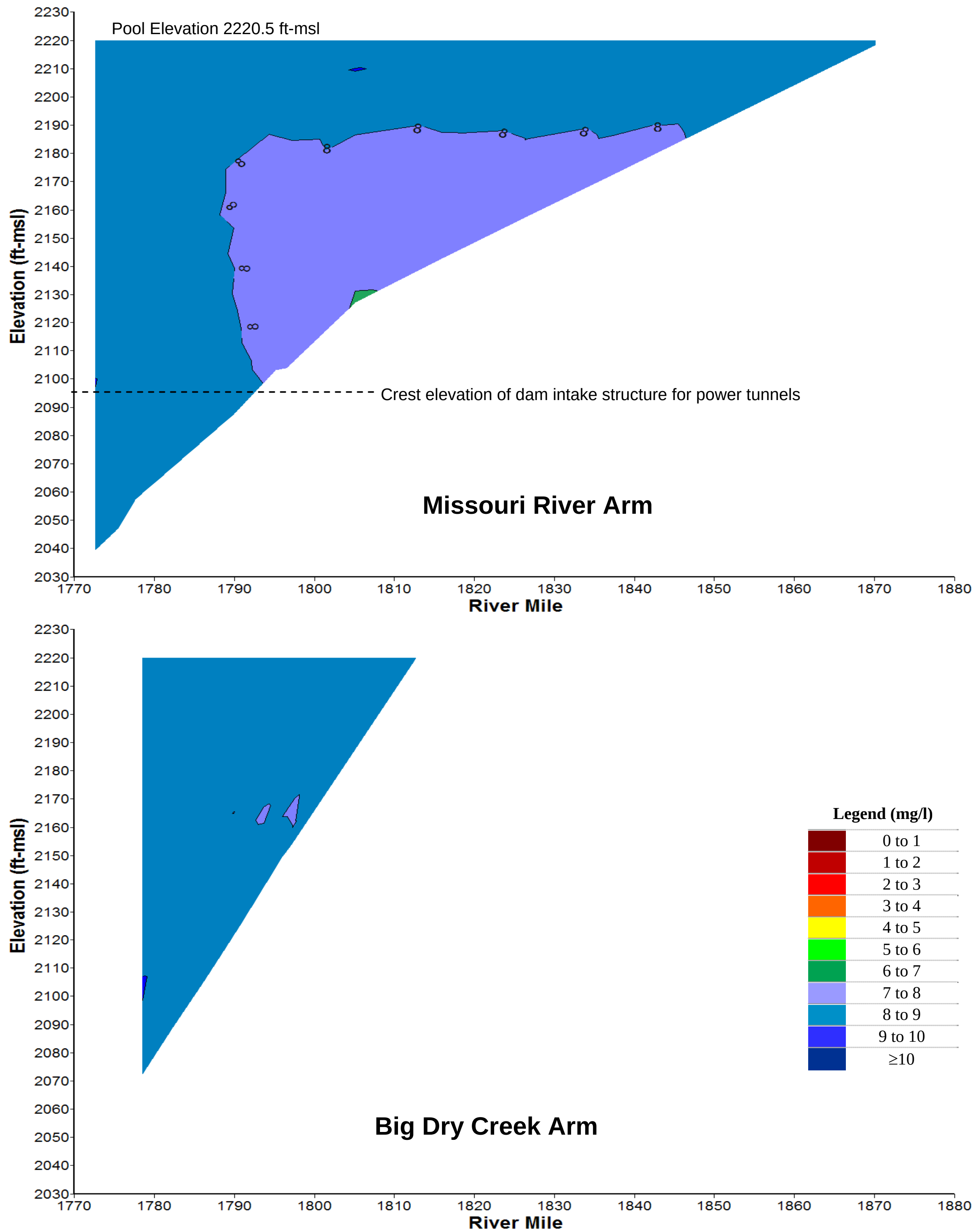


Plate 13. Longitudinal dissolved oxygen (mg/l) contour plot of Fort Peck Lake based on depth-profile dissolved oxygen concentrations monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on July 18, 2009.

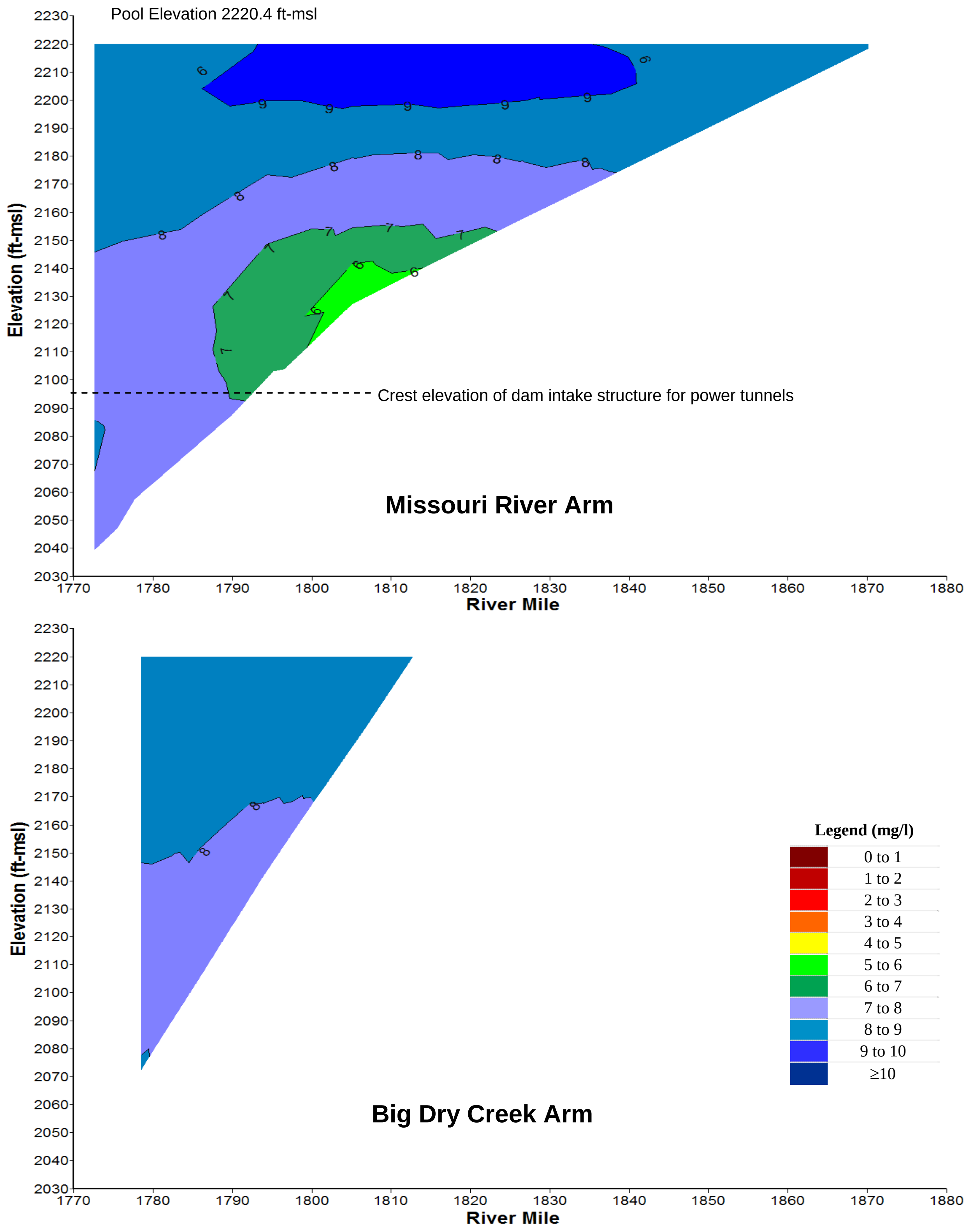


Plate 14. Longitudinal dissolved oxygen (mg/l) contour plot of Fort Peck Lake based on depth-profile dissolved oxygen concentrations monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on August 22, 2009.

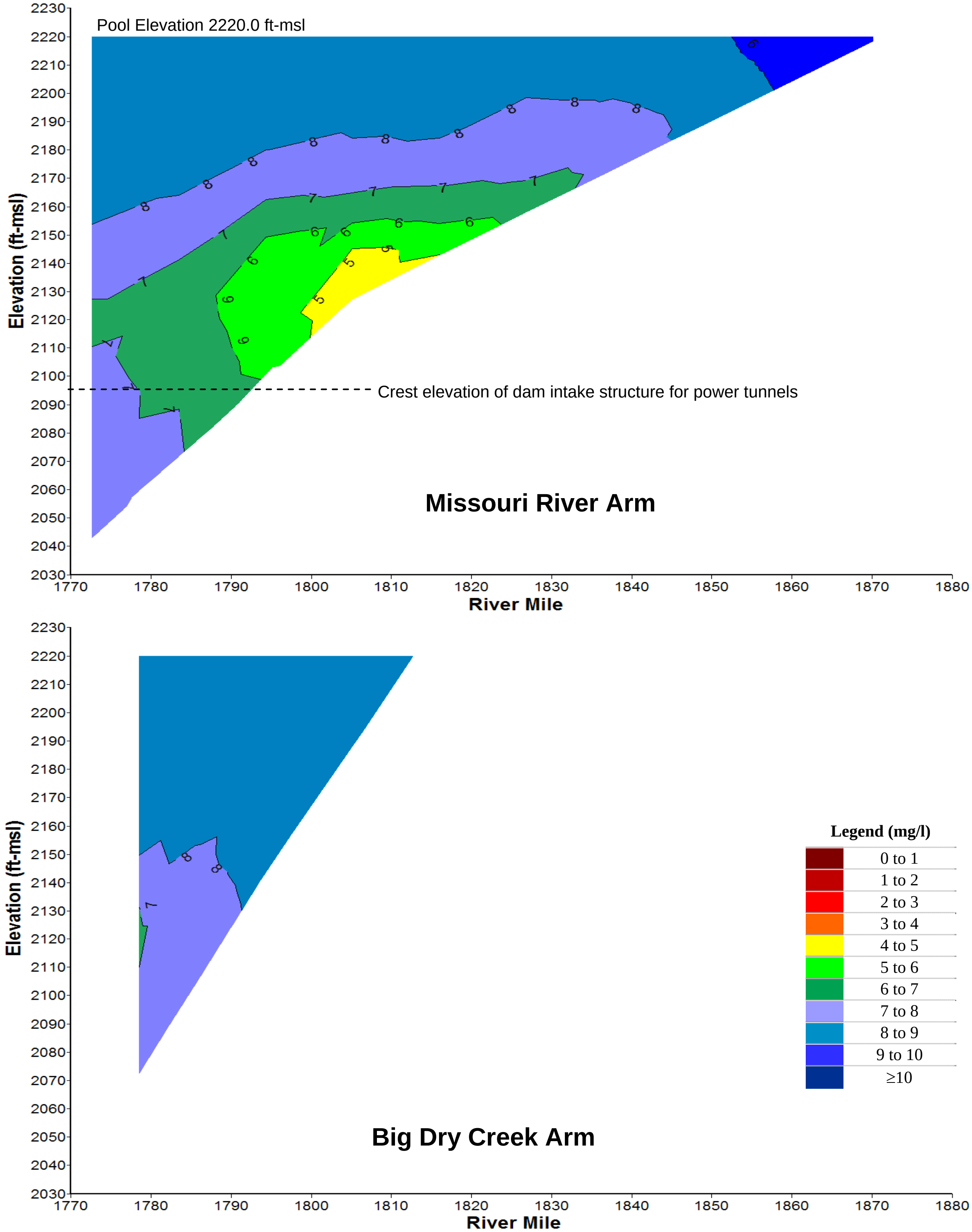


Plate 15. Longitudinal dissolved oxygen (mg/l) contour plot of Fort Peck Lake based on depth-profile dissolved oxygen concentrations monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on September 20, 2009.

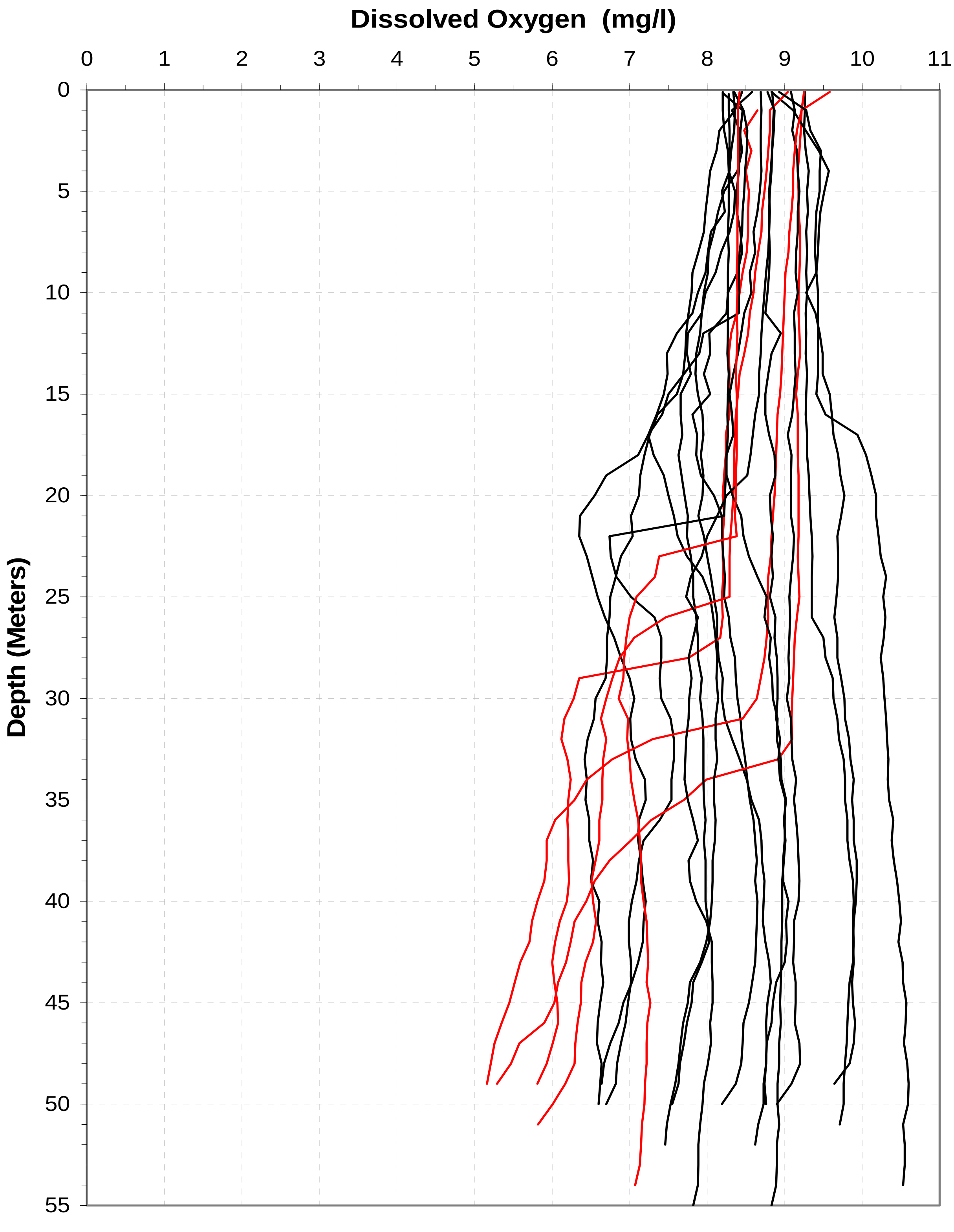


Plate 16. Dissolved oxygen depth profiles for Fort Peck Lake compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., FTPLK1772A) during the summer over the 5-year period of 2005 to 2009.
(Note: Red profile plots were measured in the month of September.)

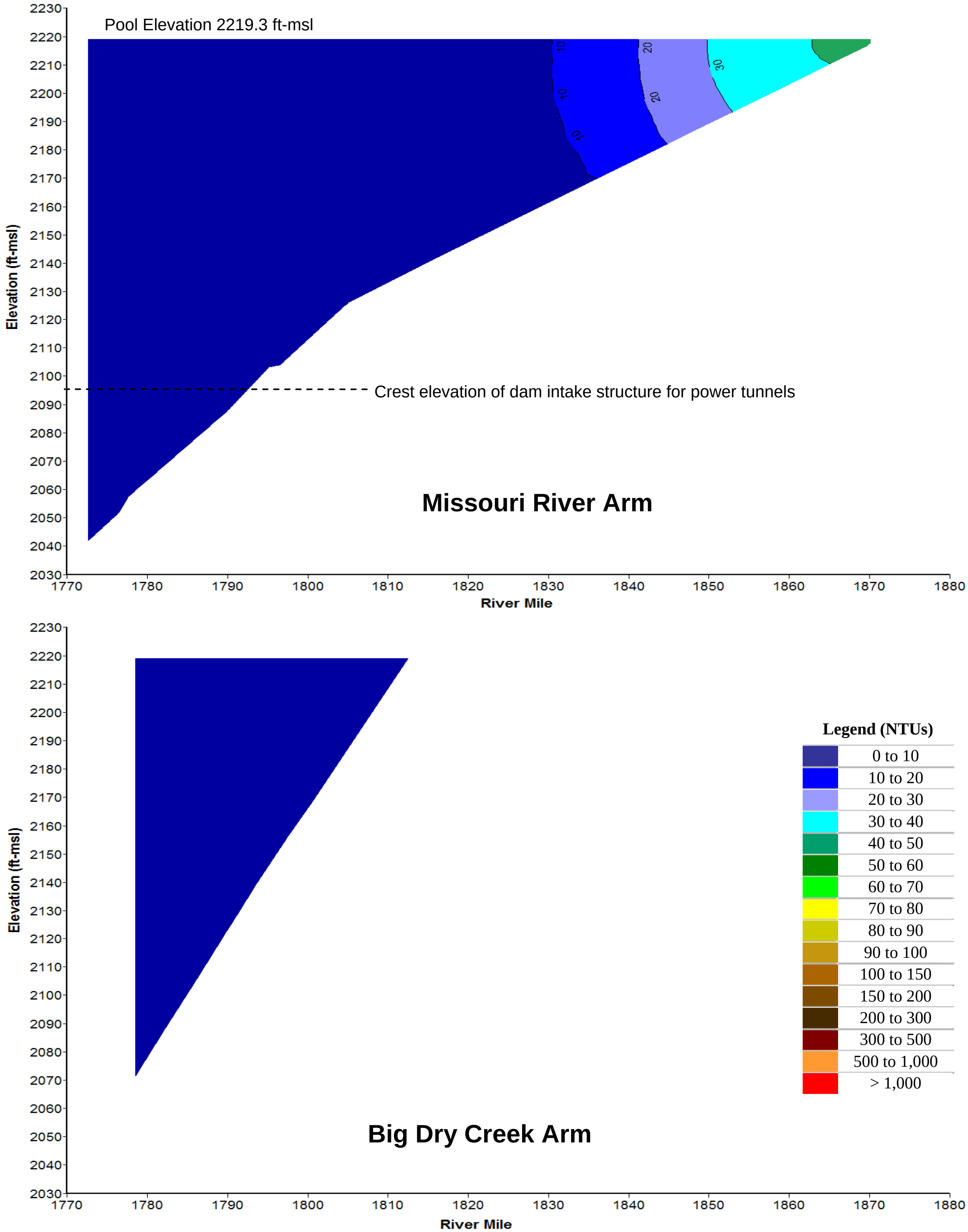


Plate 17. Longitudinal turbidity (NTU) contour plot of Fort Peck Lake based on depth-profile turbidity levels monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on June 20, 2009.

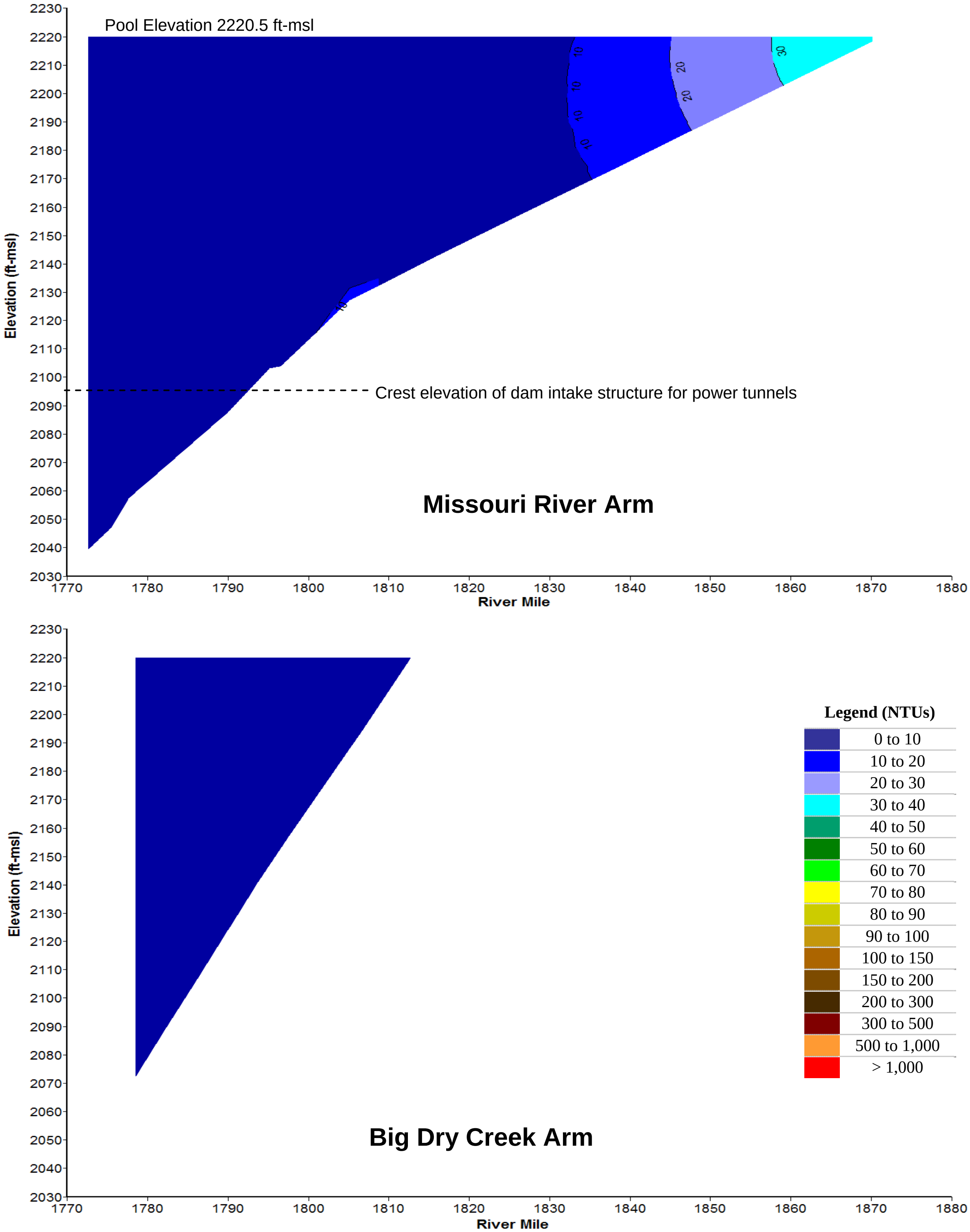


Plate 18. Longitudinal turbidity (NTU) contour plot of Fort Peck Lake based on depth-profile turbidity levels monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on July 18, 2009.

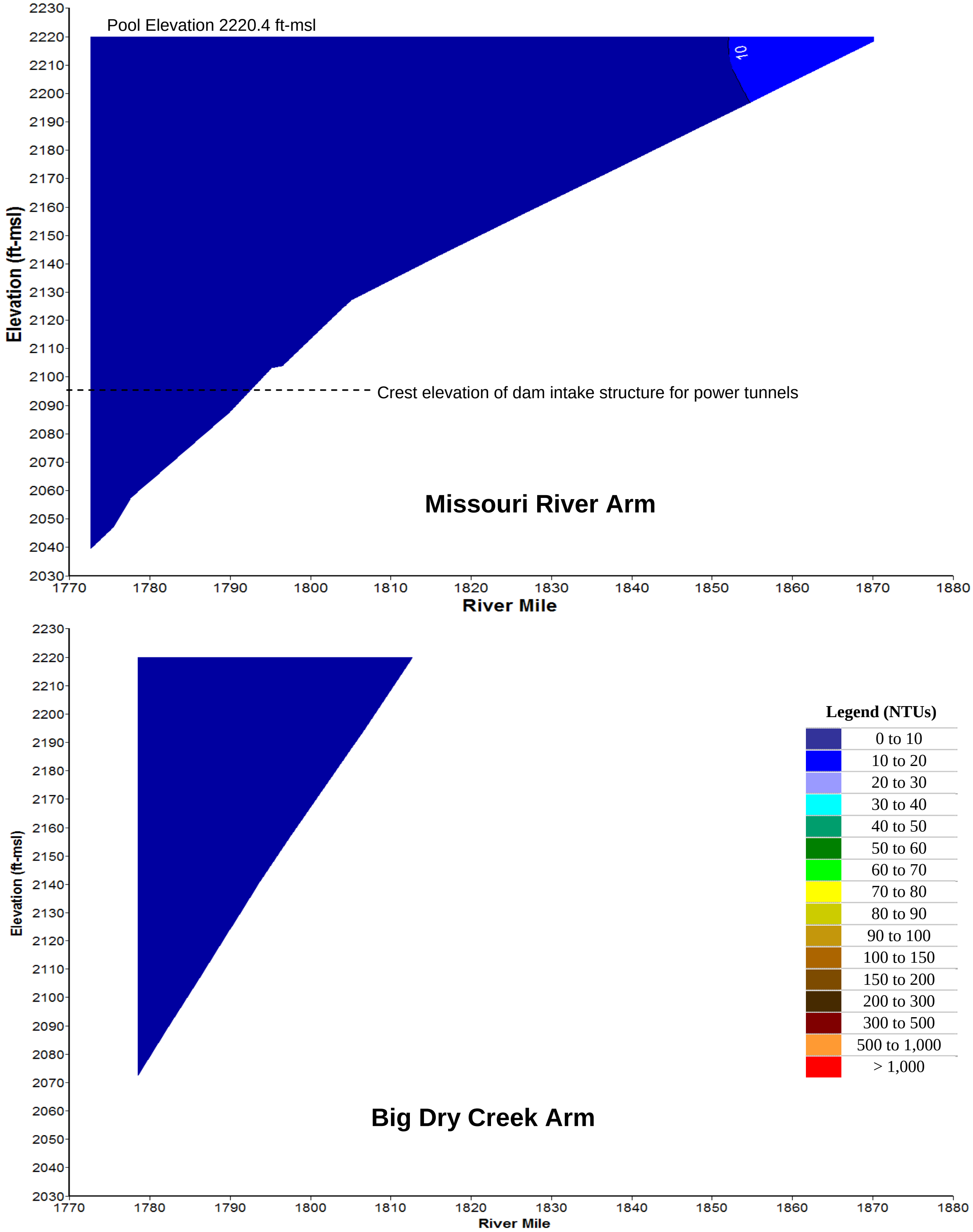


Plate 19. Longitudinal turbidity (NTU) contour plot of Fort Peck Lake based on depth-profile turbidity levels monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on August 22, 2009.

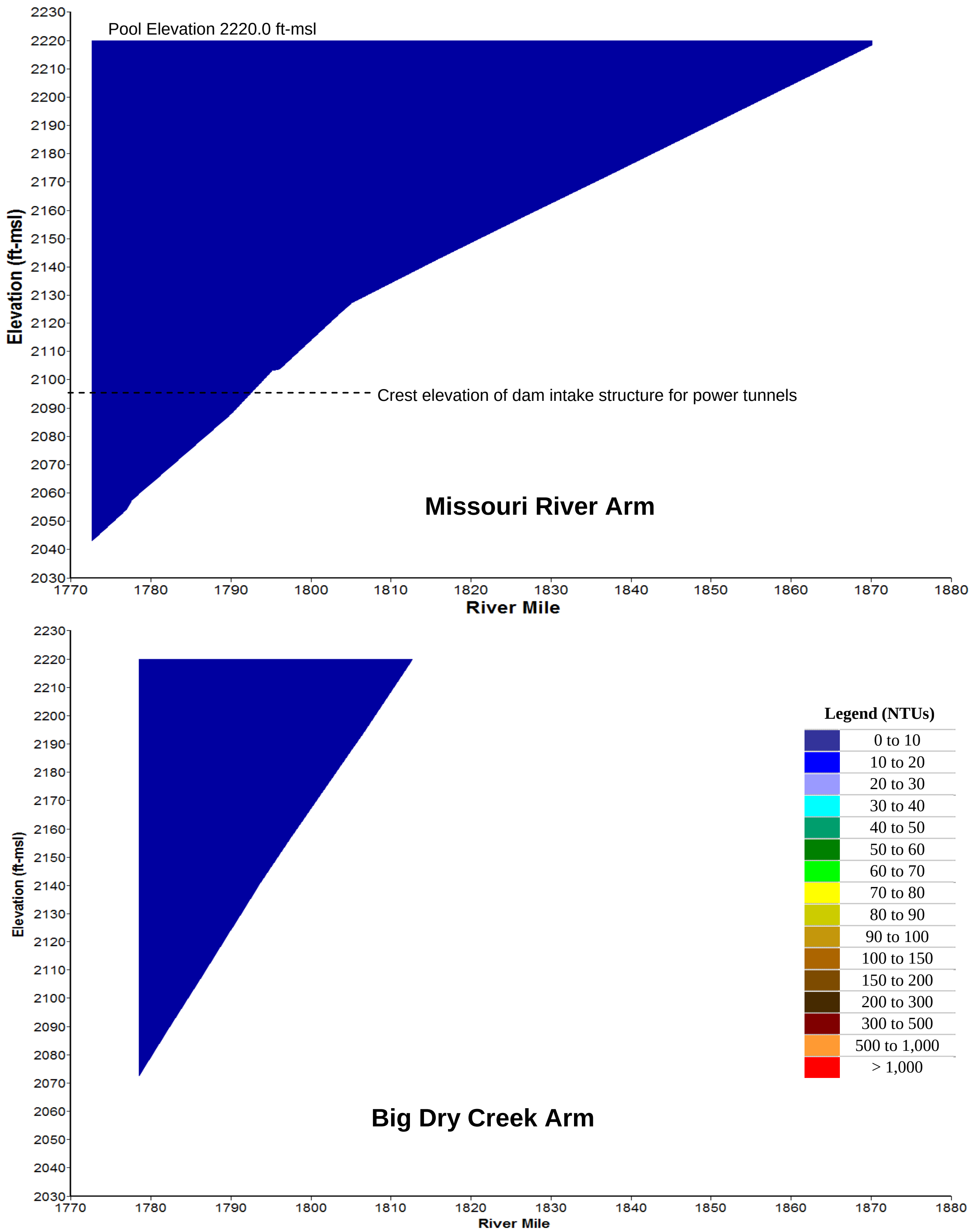


Plate 20. Longitudinal turbidity (NTU) contour plot of Fort Peck Lake based on depth-profile turbidity levels monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on September 20, 2009.

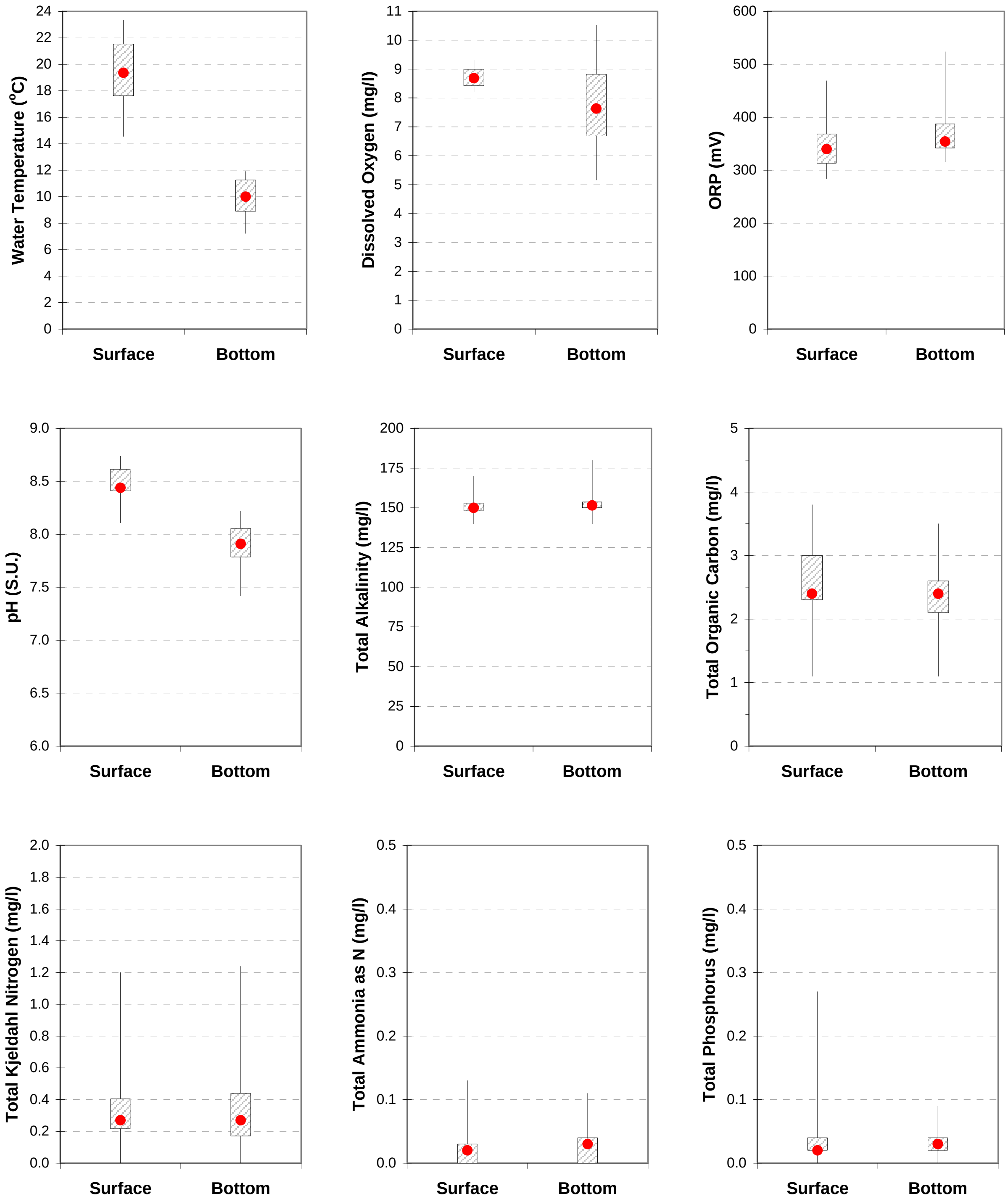


Plate 21. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Fort Peck Lake at site FTPLK1772A during the summer months of 2005 through 2009.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 22. Total biovolume, number of genera, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Fort Peck Lake at site FTPLK1772A during the 5-year period 2005 through 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
May 2005	515,757,980	10	0.92	1	<0.01	2	0.07	0	-----	0	-----	0	-----	0	-----	1.28
Jun 2005	46,921,234	5	0.90	1	<0.01	0	-----	0	-----	1	<0.01	1	0.09	0	-----	1.61
Jul 2005	156,655,118	4	0.79	1	<0.01	0	-----	2	0.07	5	0.02	2	0.11	0	-----	1.51
Aug 2005	329,301,346	7	0.46	3	<0.01	1	<0.01	1	0.05	6	0.18	2	0.30	0	-----	2.20
Sep 2005	138,703,297	7	0.38	9	0.08	0	-----	1	<0.01	5	0.05	1	0.47	0	-----	1.62
May 2006	38,868,068	6	0.99	1	0.01	0	-----	0	-----	0	-----	0	-----	1	<0.01	1.17
Jun 2006	106,214,930	4	0.89	2	0.02	1	<0.01	1	<0.01	1	0.08	0	-----	1	<0.01	1.11
Jul 2006	99,703,362	8	0.25	3	0.01	1	0.03	1	0.01	3	0.34	2	0.35	1	0.01	2.12
Aug 2006	146,573,753	6	0.85	3	0.05	0	-----	1	0.03	2	0.07	0	-----	0	-----	1.83
Sep 2006	187,114,896	4	0.95	2	<0.01	0	-----	1	0.04	2	0.01	0	-----	0	-----	1.12
May 2007	1,351,414,254	12	0.99	2	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----	0.40
Jun 2007	341,943,773	10	0.89	5	<0.01	1	0.05	1	<0.01	2	<0.01	1	<0.01	0	-----	1.49
Jul 2007	164,287,704	7	0.06	3	0.01	1	0.09	1	0.03	3	0.60	2	0.21	0	-----	1.68
Aug 2007	88,444,888	8	0.37	4	0.07	1	0.04	1	0.23	3	0.10	2	0.20	0	-----	2.16
Sep 2007	85,876,002	6	0.69	7	0.06	1	0.02	2	0.07	5	0.12	2	0.04	0	-----	2.28
May 2008	395,506,432	3	1.00	3	<0.01	0	-----	1	<0.01	0	-----	0	-----	0	-----	0.72
Jun 2008	270,305,058	8	0.99	0	-----	2	0.01	0	<0.01	0	-----	0	-----	0	-----	1.09
Jul 2008	777,031	8	0.97	0	-----	1	0.01	1	0.01	2	0.01	2	0.01	0	-----	1.27
Aug 2008	38,049,881	9	0.15	2	0.24	0	-----	1	0.10	2	0.45	2	0.05	0	-----	1.76
Sep 2008	132,911,993	5	0.89	3	0.01	0	-----	1	0.03	4	0.03	2	0.04	0	-----	1.15
May 2009	689,210,292	9	0.96	2	<0.01	1	<0.01	2	0.03	1	0.01	0	-----	1	<0.01	0.71
Jun 2009	506,500,283	10	0.72	0	-----	2	0.10	1	<0.01	3	0.17	0	-----	1	<0.01	1.85
Jul 2009	160,128,878	7	0.57	6	0.02	0	-----	1	0.06	5	0.32	1	<0.01	0	-----	1.71
Aug 2009	658,431,000	8	0.35	3	0.02	1	0.01	2	0.04	4	0.42	1	0.16	1	<0.01	2.02
Sep 2009	411,514,973	5	0.05	5	0.04	0	-----	2	0.69	1	0.07	0	-----	2	0.16	1.21
Mean*	**282,444,657**	**7.0**	**0.68**	**2.8**	**0.03**	**0.7**	**0.03**	**1.0**	**0.07**	**2.4**	**0.15**	**0.9**	**0.15**	**0.3**	**0.02**	**1.48**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 23. Total biovolume, number of genera, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Fort Peck Lake at site FTPLK1805DW during the 5-year period 2005 through 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2005	1,065,980,294	6	0.97	3	0.01	2	0.02	1	<0.01	2	<0.01	0	-----	0	-----	1.39
Jul 2005	56,454,155	4	0.62	3	0.01	0	-----	2	0.27	4	0.06	1	0.04	0	-----	1.91
Aug 2005	104,295,158	8	0.36	3	0.14	0	-----	1	0.12	3	0.37	1	<0.01	0	-----	2.21
Sep 2005	224,860,040	4	0.56	4	0.09	2	0.05	2	0.15	3	0.06	2	0.08	0	-----	2.21
Jun 2006	462,062,083	8	0.94	7	0.02	2	0.01	1	0.02	0	-----	0	-----	1	<0.01	1.45
Jul 2006	339,425,190	5	0.19	5	0.10	2	0.03	1	0.22	3	0.43	1	0.03	0	-----	1.95
Oct 2006	342,710,099	9	0.72	12	0.10	1	0.01	1	0.07	3	0.10	1	<0.01	0	-----	2.19
Jun 2007	610,342,167	8	0.67	8	0.05	2	0.13	2	0.07	1	<0.01	1	0.08	0	-----	1.86
Jul 2007	110,206,693	5	0.19	5	0.05	1	<0.01	1	0.22	1	0.08	2	0.46	0	-----	1.64
Aug 2007	301,438,256	9	0.73	10	0.07	1	<0.01	1	0.02	5	0.16	1	0.02	0	-----	1.39
Sep 2007	205,529,265	9	0.34	10	0.19	1	0.01	2	0.10	6	0.01	1	0.35	0	-----	2.01
May 2008	73,487,404	5	0.90	2	0.03	1	0.04	1	0.03	0	-----	0	-----	0	-----	0.76
Jun 2008	1,285,632,120	8	0.96	2	0.02	1	<0.01	1	0.01	0	-----	0	-----	0	-----	1.32
Aug 2008	29,477,027	1	<0.01	4	0.01	1	0.03	1	0.68	6	0.16	1	0.11	0	-----	1.15
Sep 2008	577,974,858	6	0.90	3	0.03	1	<0.01	1	0.06	3	0.01	1	<0.01	0	-----	0.87
Jun 2009	262,828,233	8	0.90	5	0.01	1	0.03	1	0.01	3	<0.01	1	0.03	1	0.01	0.86
Jul 2009	1,520,296,603	7	0.33	6	0.01	2	0.04	2	0.21	4	0.13	1	0.29	1	<0.01	1.86
Aug 2009	752,809,103	8	0.32	7	0.05	2	0.14	1	0.03	4	0.31	2	0.15	0	-----	2.32
Sep 2009	527,582,644	8	0.51	10	0.05	2	0.01	2	0.16	4	0.07	1	0.05	1	0.15	1.99
Mean*	**465,967,968**	**6.6**	**0.58**	**5.7**	**0.05**	**1.3**	**0.03**	**1.3**	**0.13**	**2.9**	**0.12**	**0.9**	**0.11**	**0.2**	**0.04**	**1.65**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 24. Total biovolume, number of genera, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Fort Peck Lake at site FTPLKBDCA02 during the 5-year period 2005 through 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	**Percent Comp.**	**No. of Genera**	**Percent Comp.**	**No. of Genera**	**Percent Comp.**	**No. of Genera**	**Percent Comp.**	**No. of Genera**	**Percent Comp.**	**No. of Genera**	**Percent Comp.**	**No. of Genera**	**Percent Comp.**	
Jun 2005	135,109,593	1	0.31	2	0.02	1	0.64	2	0.01	1	0.02	0	-----	0	-----	0.88
Jul 2005	60,324,919	5	0.47	1	0.03	0	-----	1	0.43	3	0.08	0	-----	0	-----	1.59
Aug 2005	155,331,963	7	0.41	5	0.10	1	0.03	0	-----	5	0.30	1	0.16	0	-----	2.22
Sep 2005	95,486,617	7	0.60	9	0.06	0	-----	2	0.10	5	0.16	1	0.09	0	-----	2.17
Jun 2006	91,137,918	8	0.91	3	0.01	0	-----	1	<0.01	2	0.02	0	-----	2	0.06	0.89
Jul 2006	73,204,385	6	0.11	5	0.07	0	-----	1	0.04	2	0.67	0	-----	2	0.11	1.48
Aug 2006	86,290,748	5	0.60	4	0.05	0	-----	1	0.14	2	0.21	0	-----	0	-----	1.81
Oct 2006	105,358,293	4	0.65	5	0.01	0	-----	1	0.12	2	0.21	1	<0.01	0	-----	1.58
Jun 2007	361,946,003	7	0.72	5	<0.01	1	0.06	1	0.20	1	<0.01	1	0.01	0	----	1.45
Jul 2007	197,258,569	8	0.06	2	0.01	1	0.14	1	0.06	3	0.48	2	0.26	0	-----	1.74
May 2008	54,050,825	8	0.96	1	<0.01	1	0.03	1	0.01	0	-----	0	-----	0	-----	1.43
Jun 2008	359,698,227	8	1.00	2	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----	0.65
Jul 2008	317,482	2	0.91	3	0.01	1	<0.01	1	0.01	2	0.07	1	0.01	0	-----	1.12
Aug 2008	22,438,138	2	0.02	2	0.05	0	-----	1	0.51	3	0.41	1	0.01	0	-----	1.16
Sep 2008	122,457,717	4	0.82	1	<0.01	0	-----	1	0.11	0	-----	1	0.07	0	-----	0.97
May 2009	1,509,380,056	8	0.98	1	<0.01	1	<0.01	1	0.02	1	<0.01	0	-----	0	-----	0.57
Jun 2009	85,517,820	8	0.77	2	<0.01	1	0.19	1	0.01	2	0.02	0	-----	0	-----	1.38
Jul 2009	31,188,045	6	0.81	4	0.01	0	-----	1	0.05	5	0.08	1	0.05	0	-----	1.39
Aug 2009	155,000,267	7	0.19	4	0.05	1	0.02	1	0.27	3	0.45	1	0.01	0	-----	1.86
Sep 2009	148,371,881	8	0.22	6	0.13	0	-----	1	0.53	0	-----	1	0.01	2	0.11	1.42
Mean*	**192,493,473**	**6.0**	**0.58**	**3.4**	**0.03**	**0.5**	**0.11**	**1.1**	**0.14**	**2.1**	**0.20**	**0.6**	**0.06**	**0.3**	**0.09**	**1.39**

* Mean percent composition represents the mean when taxa of that division are present.

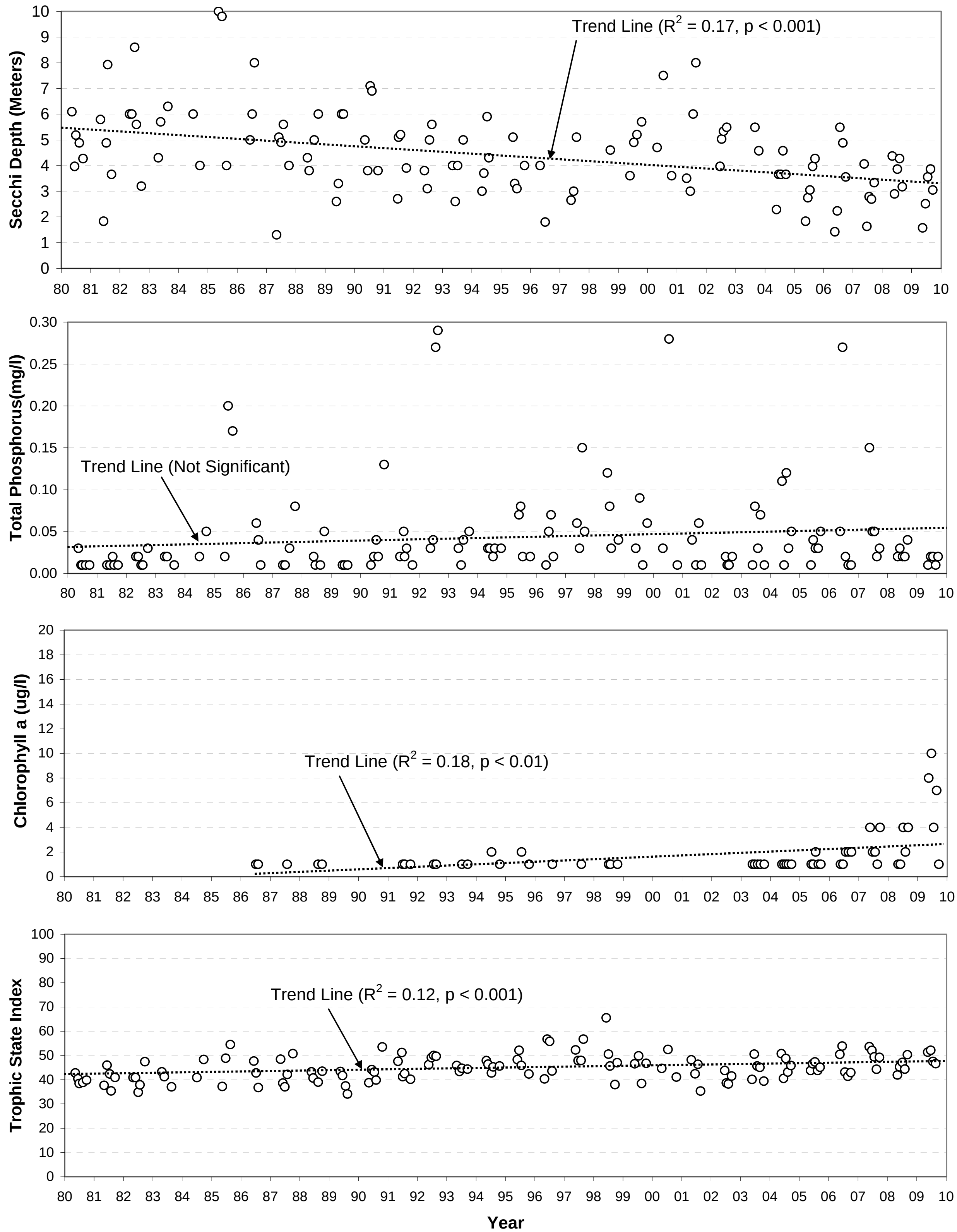


Plate 25. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Fort Peck Lake at site FTPLK1772A over the 30-year period of 1980 through 2009.

Plate 26. Summary of monthly (April through September) water quality conditions monitored in the Missouri River near Landusky, Montana at monitoring site FTPNFMORR1 during the 5-year period 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[(A)]	No. of Obs.	Mean[(B)]	Median	Min.	Max.	State WQS Criteria[(C)]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	23	8,439	7,830	3,978	17,500	-----	-----	-----
Water Temperature (°C)	0.1	24	17.8	17.0	9.2	26.4	26.7[(1,2)]	0	0%
Dissolved Oxygen (mg/l)	0.1	24	8.8	9.0	7.0	10.7	5.0[(1,3)]	0	0%
Dissolved Oxygen (% Sat.)	0.1	24	95.7	96.6	81.2	103.6	-----	-----	-----
pH (S.U.)	0.1	24	8.5	8.6	8.0	9	6.5[(1,3)], 9.0[(1,2)]	0, 1	0%, 4%
Specific Conductance (umho/cm)	1	24	455	435	376	696	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	24	328	322	266	436	-----	-----	-----
Turbidity (NTU)	1	24	343	38	1	3,000	-----	-----	-----
Alkalinity, Total (mg/l)	7	23	144	144	120	175	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	22	2.7	2.8	1.1	4.2	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	21	21	12	4	171	-----	-----	-----
Chloride, Dissolved (mg/l)	1	21	8	9	6	11	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	23	309	288	250	509	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	23	-----	0.03	n.d.	0.46	2.6 [(1,2,4)], 0.71[(1,4,5)]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	23	1.0	0.7	0.2	5.9	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	23	-----	n.d.	n.d.	0.20	-----	-----	-----
Nitrogen, Total (mg/l)	0.1	23	1.1	0.7	0.2	6.1	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	23	-----	n.d.	n.d.	0.15	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	23	0.42	0.08	0.03	4.70	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	23	-----	n.d.	n.d.	0.09	-----	-----	-----
Sulfate (mg/l)	1	23	89	79	56	229	-----	-----	-----
Suspended Solids, Total (mg/l)	4	23	572	78	16	7,437	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for B-3 classified waters.
- (2) Daily maximum criterion (monitoring results directly comparable to criterion).
- (3) Daily minimum criterion (monitoring results directly comparable to criterion).
- (4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (5) 30-day average criterion (monitoring results not directly comparable to criterion).

Plate 27. Summary of annual metals and pesticide levels monitored in the Missouri River near Landusky, Montana at monitoring site FTPNFMORR1 during the 5-year period 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	3	-----	n.d.	n.d.	n.d.	750[1], 87[2]	0	0%
Aluminum, Total (ug/l)	25	3	1,227	1,180	800	7,700	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	3	-----	0.6	n.d.	0.6	-----	-----	-----
Antimony, Total (ug/l)	0.5	0	-----	1.0	n.d.	5.0	5.6[1]	0	0%
Arsenic, Dissolved (ug/l)	1	3	13	13	11	14	-----	-----	-----
Arsenic, Total (ug/l)	1	3	14	14	14	15	340[1], 150[2], 10[3]	0, 0, 3	0%, 0%, 100%
Barium, Dissolved (ug/l)	5	3	59	54	54	70	-----	-----	-----
Barium, Total (ug/l)	5	3	71	70	69	74	2,000[3]	0	0%
Beryllium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Beryllium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	4[3]	0	0%
Cadmium, Dissolved (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Cadmium, Total (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	3.9[1], 0.42[2], 5[3]	0	0%
Chromium, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Chromium, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	2,944[1], 141[2], 100[3]	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Copper, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	25[1], 16[2], 1,300[3]	0	0%
Hardness, Total (mg/l)	0.4	3	185	182	171	202	-----	-----	-----
Iron, Dissolved (ug/l)	40	10[A]	-----	n.d.	n.d.	230	-----	-----	-----
Iron, Total (ug/l)	40	10[A]	22,327	1,483	684	145,000	1,000[2], 300[4]	8, 10	80%, 100%
Lead, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Lead, Total (ug/l)	0.5	3	0.9	1.0	0.6	1.1	175[1], 6.8[2], 15[3]	0	0%
Manganese, Dissolved (ug/l)	2	10[A]	6	5	n.d.	20	-----	-----	-----
Manganese, Total (ug/l)	2	10[A]	247	35	21	1,460	50[4]	4	40%
Mercury, Dissolved (ug/l)	0.02	3	-----	n.d.	n.d.	0.03	-----	-----	-----
Mercury, Total (ug/l)	0.02	3	-----	n.d.	n.d.	0.05	1.7[1], 0.91[2], 0.05[3]	0	0%
Nickel, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Nickel, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	779[1], 87[2], 100[3]	0	0%
Selenium, Total (ug/l)	1	3	-----	n.d.	n.d.	1	20[1], 5[2], 50[3]	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Silver, Total (ug/l)	1	3	-----	n.d.	n.d.	n.d.	11[1], 100[3]	0	0%
Thallium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Total (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	0.24[3]	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Zinc, Total (ug/l)	10	3	-----	10	n.d.	70	199[6,7], 2,000[3]	0	0%
Pesticide Scan (ug/l)[D]	0.05	3	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Results for iron (dissolved and total) and manganese (dissolved and total) include some monthly samples.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Acute criterion for aquatic life.

(2) Chronic criterion for aquatic life.

(3) Human health criterion for surface waters.

(4) Secondary Maximum Contaminant Level based on aesthetic properties.

Note: Some of Montana's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

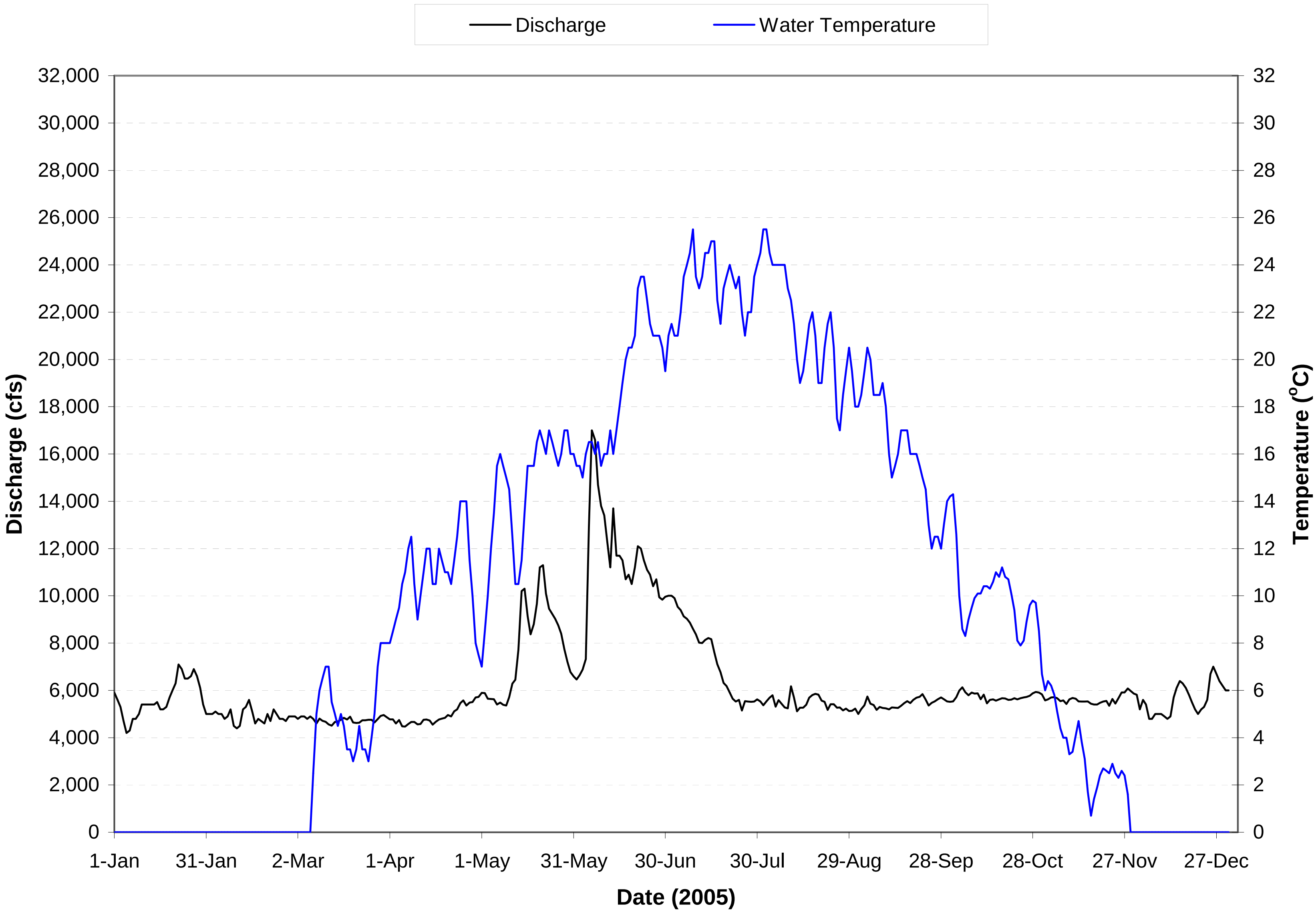


Plate 28. Mean daily discharge and water temperature of the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) for 2005. Means based on measurements recorded at USGS gaging station 06115200.

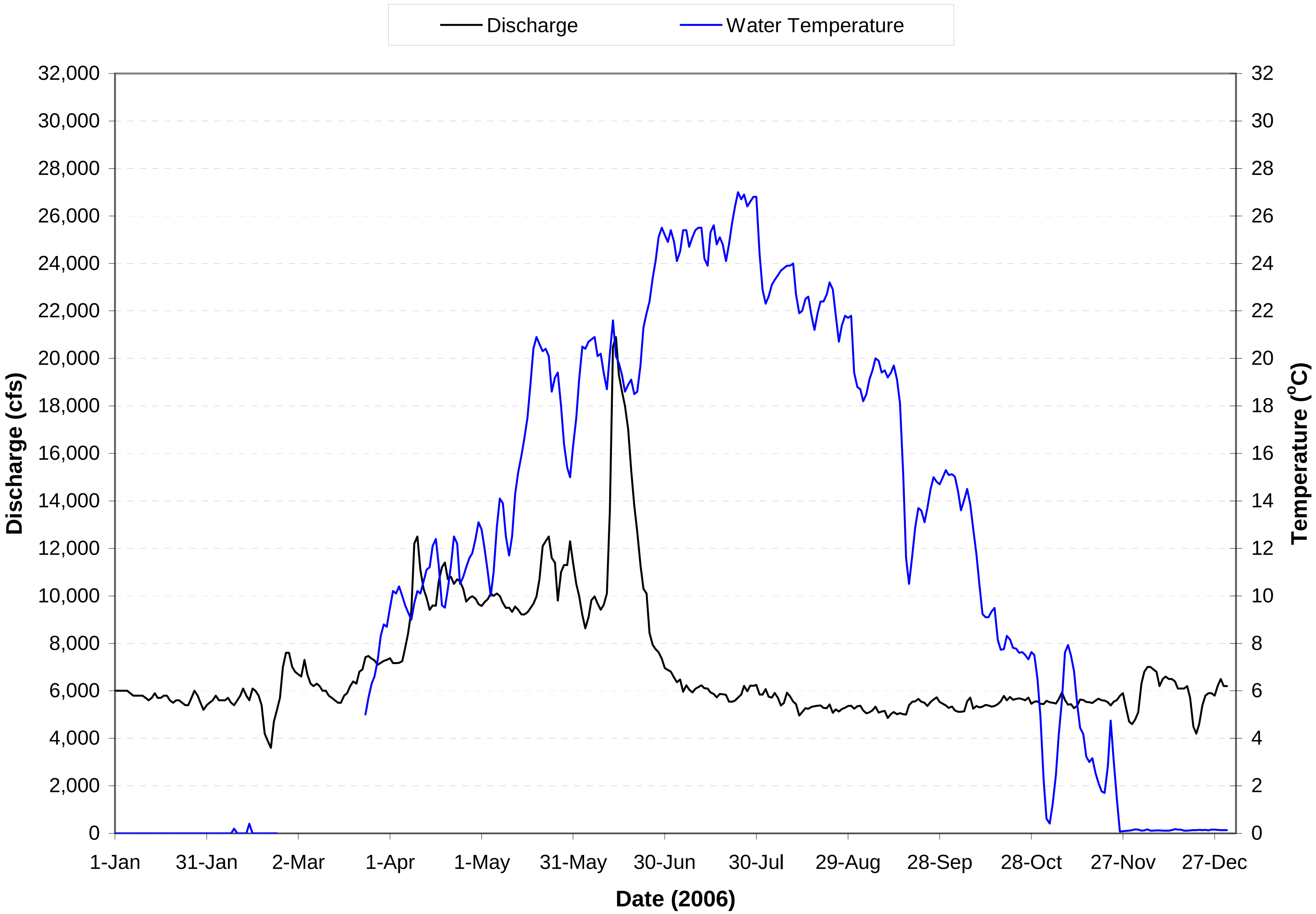


Plate 29. Mean daily discharge and water temperature of the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) for 2006. Means based on measurements recorded at USGS gaging station 06115200.

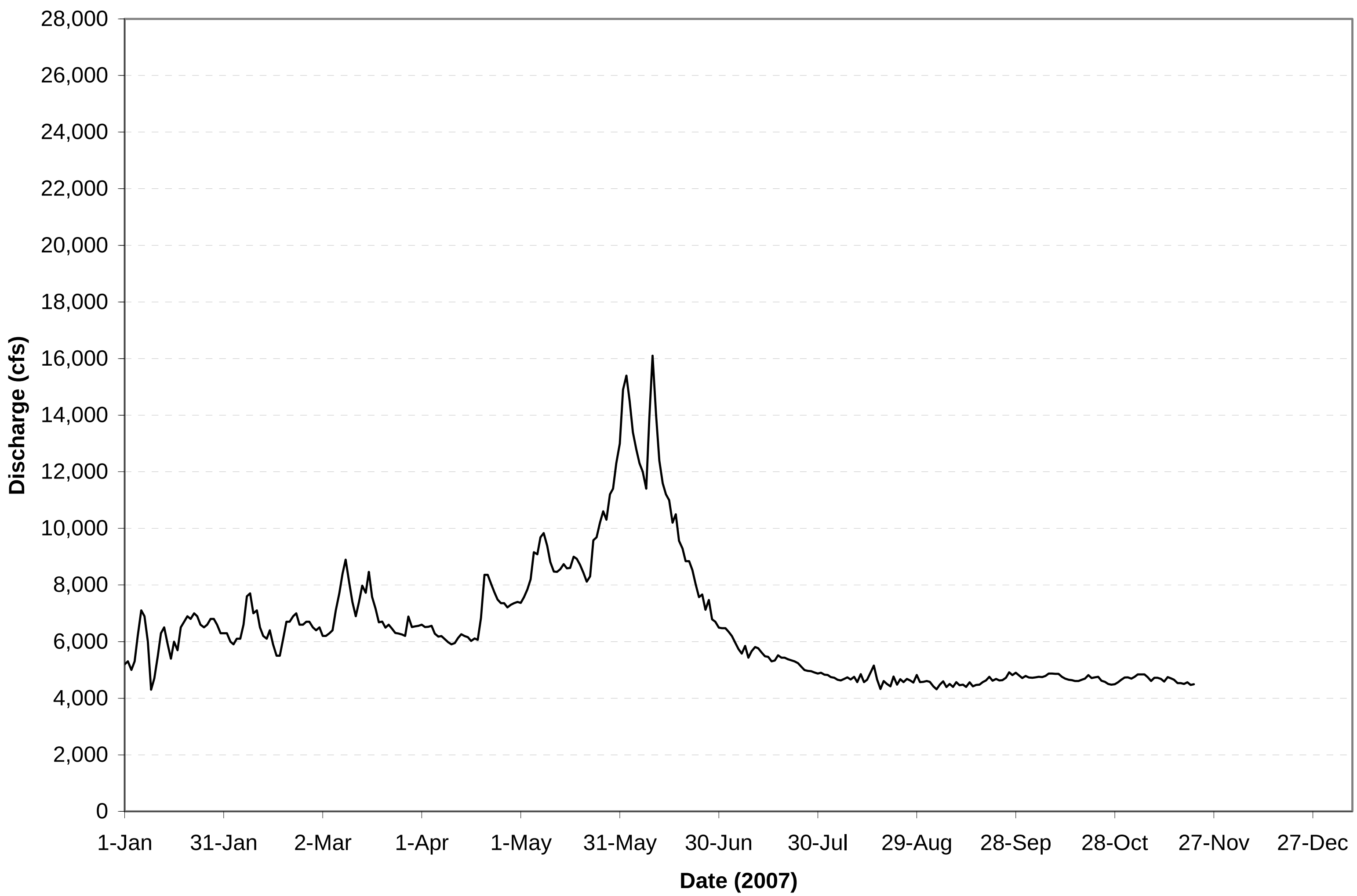


Plate 30. Mean daily discharge of the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) for 2007. Means based on measurements recorded at USGS gaging station 06115200.

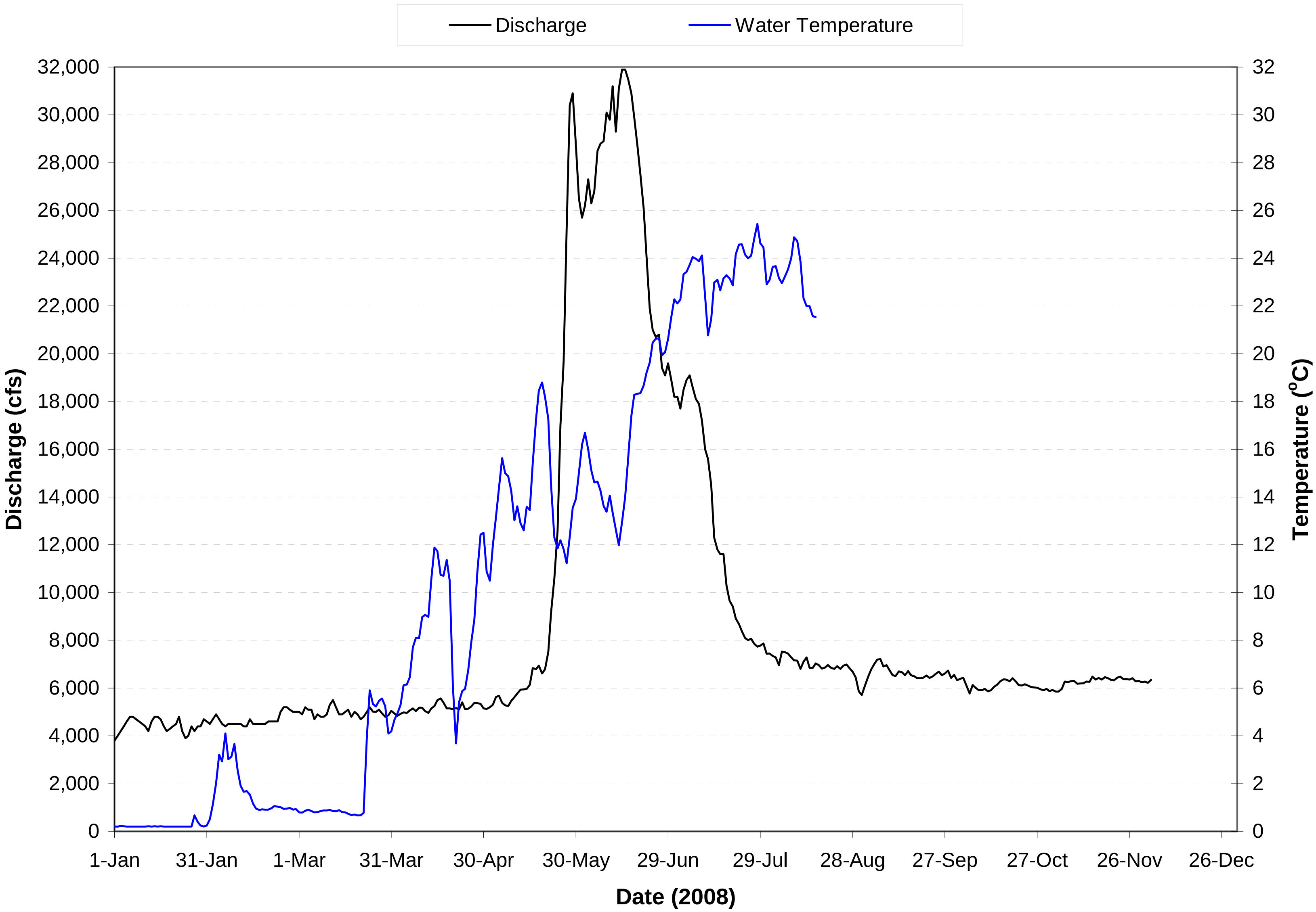


Plate 31. Mean daily discharge and water temperature of the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) for 2008. Means based on measurements recorded at USGS gaging station 06115200.

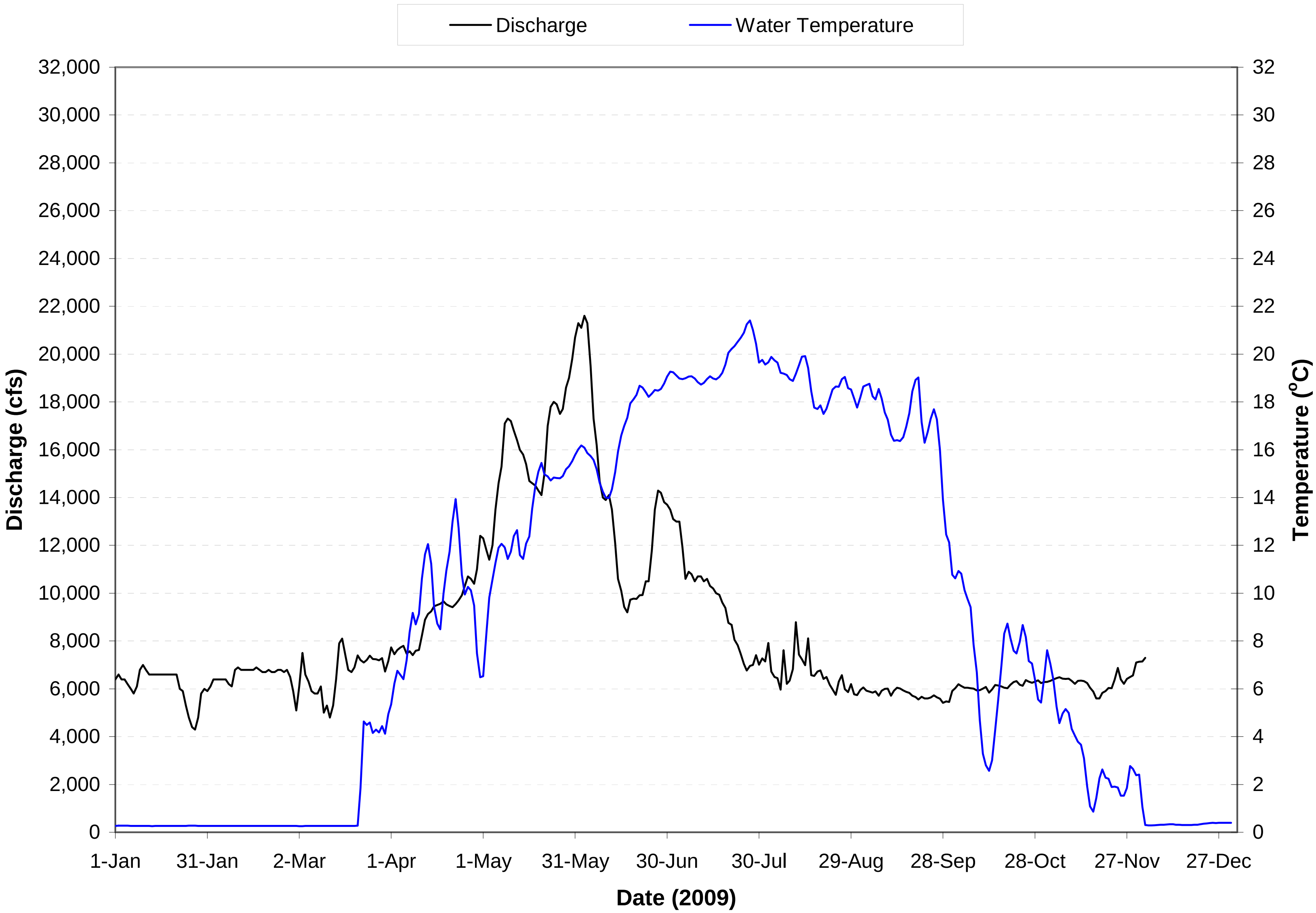


Plate 32. Mean daily discharge and water temperature of the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) for 2009. Means based on measurements recorded at USGS gaging station 06115200.

Plate 33. Summary of monthly water quality conditions monitored from water discharged through Fort Peck Dam (i.e., site FTPPP1) during the 5-year period of January 2005 through December 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Dam Discharge (cfs)	1	52	6,239	5,893	3,000	12,513	-----	-----	-----
Water Temperature (°C)	0.1	50	8.9	9.5	1.4	17.3	19.4[1,4]	0	0%
Dissolved Oxygen (mg/l)	0.1	50	10.2	10.3	6.0	13.8	8.0[1,2,4], 5.0[1,3,4]	7, 0	14%, 0%
Dissolved Oxygen (% Sat.)	0.1	50	91.1	92.4	62.7	107.9	-----	-----	-----
pH (S.U.)	0.1	46	8.3	8.3	7.6	8.7	6.5[1,5], 9.0[1,4]	0	0%
Specific Conductance (umho/cm)	1	50	533	540	443	704	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	33	364	350	285	511	-----	-----	-----
Turbidity (NTU)	0.1	35	-----	1	n.d.	23	-----	-----	-----
Alkalinity, Total (mg/l)	7	51	158	155	140	180	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	50	2.6	2.5	n.d.	5.3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	39	8	9	n.d.	41	-----	-----	-----
Chloride, Dissolved (mg/l)	1	38	9	9	7	17	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	51	368	358	314	496	-----	-----	-----
Hardness, Total (mg/l)	0.4	5	203	205	174	217	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	51	-----	0.02	n.d.	0.34	4.7 [1,4,6], 1.4 [1,4,7]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	51	0.4	0.3	n.d.	2.2	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	51	-----	n.d.	n.d.	0.11	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	43	-----	n.d.	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	51	-----	0.03	n.d.	0.14	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	51	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	51	131	123	57	217	-----	-----	-----
Suspended Solids, Total (mg/l)	4	51	-----	n.d.	n.d.	19	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for B-3 classified waters.
- (2) Early life stages.
- (3) Non-early life stages.
- (4) Daily maximum criterion (monitoring results directly comparable to criterion).
- (5) Daily minimum criterion (monitoring results directly comparable to criterion).
- (6) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).

Plate 34. Summary of annual metals and pesticide levels monitored from water discharged through Fort Peck Dam (i.e., site FTPPP1) during the 5-year period of January 2005 through December 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	4	-----	n.d.	n.d.	n.d.	750[1], 87[2]	0	0%
Aluminum, Total (ug/l)	25	3	108	70	50	205	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	3	-----	0.5	n.d.	0.7	-----	-----	-----
Antimony, Total (ug/l)	0.5	3	-----	0.5	n.d.	0.7	5.6[1]	0	0%
Arsenic, Dissolved (ug/l)	1	6	-----	2	n.d.	5	-----	-----	-----
Arsenic, Total (ug/l)	1	3	4	4	4	5	340[1], 150[2], 10[3]	0, 0, 3	0%, 0%, 100%
Barium, Dissolved (ug/l)	5	3	41	40	39	45	-----	-----	-----
Barium, Total (ug/l)	5	3	43	40	39	50	2,000[3]	0	0%
Beryllium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Beryllium, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	4[3]	0	0%
Cadmium, Dissolved (ug/l)	0.2	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Cadmium, Total (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	4.4[1], 0.46[2], 5[3]	0	0%
Chromium, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Chromium, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	3,246[1], 155[2], 100[3]	0	0%
Copper, Dissolved (ug/l)	2	6	-----	2	n.d.	4	-----	-----	-----
Copper, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	28[1], 17[2], 1,300[3]	0	0%
Hardness, Total (mg/l)	0.4	5	203	205	174	217	-----	-----	-----
Iron, Dissolved (ug/l)	40	26[A]	-----	n.d.	n.d.	40	-----	-----	-----
Iron, Total (ug/l)	40	26[A]	195	85	n.d.	2,015	1,000[2], 300[4]	1, 2	4%, 8%
Lead, Dissolved (ug/l)	0.5	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Lead, Total (ug/l)	0.5	3	-----	1.0	n.d.	2.0	204[1], 7.9[2], 15[3]	0	0%
Manganese, Dissolved (ug/l)	2	26[A]	-----	1	n.d.	10	-----	-----	-----
Manganese, Total (ug/l)	2	26[A]	-----	6	n.d.	33	50[4]	0	0%
Mercury, Dissolved (ug/l)	0.02	6	-----	n.d.	n.d.	0.03	-----	-----	-----
Mercury, Total (ug/l)	0.02	7	-----	n.d.	n.d.	0.03	1.7[1], 0.91[2], 0.05[3]	0	0%
Nickel, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Nickel, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	861[1], 96[2], 100[3]	0	0%
Selenium, Total (ug/l)	1	3	-----	n.d.	n.d.	1	20[1], 5[2], 50[3]	0	0%
Silver, Dissolved (ug/l)	1	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Silver, Total (ug/l)	1	3	-----	n.d.	n.d.	n.d.	14[1], 100[3]	0	0%
Thallium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Total (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	0.24[3]	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	10	-----	-----	-----
Zinc, Total (ug/l)	10	3	-----	10	n.d.	40	220[6,7], 2,000[3]	0	0%
Pesticide Scan (ug/l)[D]	0.05	4	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Results for iron (dissolved and total) and manganese (dissolved and total) include some monthly samples.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Acute criterion for aquatic life.
- (2) Chronic criterion for aquatic life.
- (3) Human health criterion for surface waters.
- (4) Secondary Maximum Contaminant Level based on aesthetic properties.

Note: Some of Montana's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

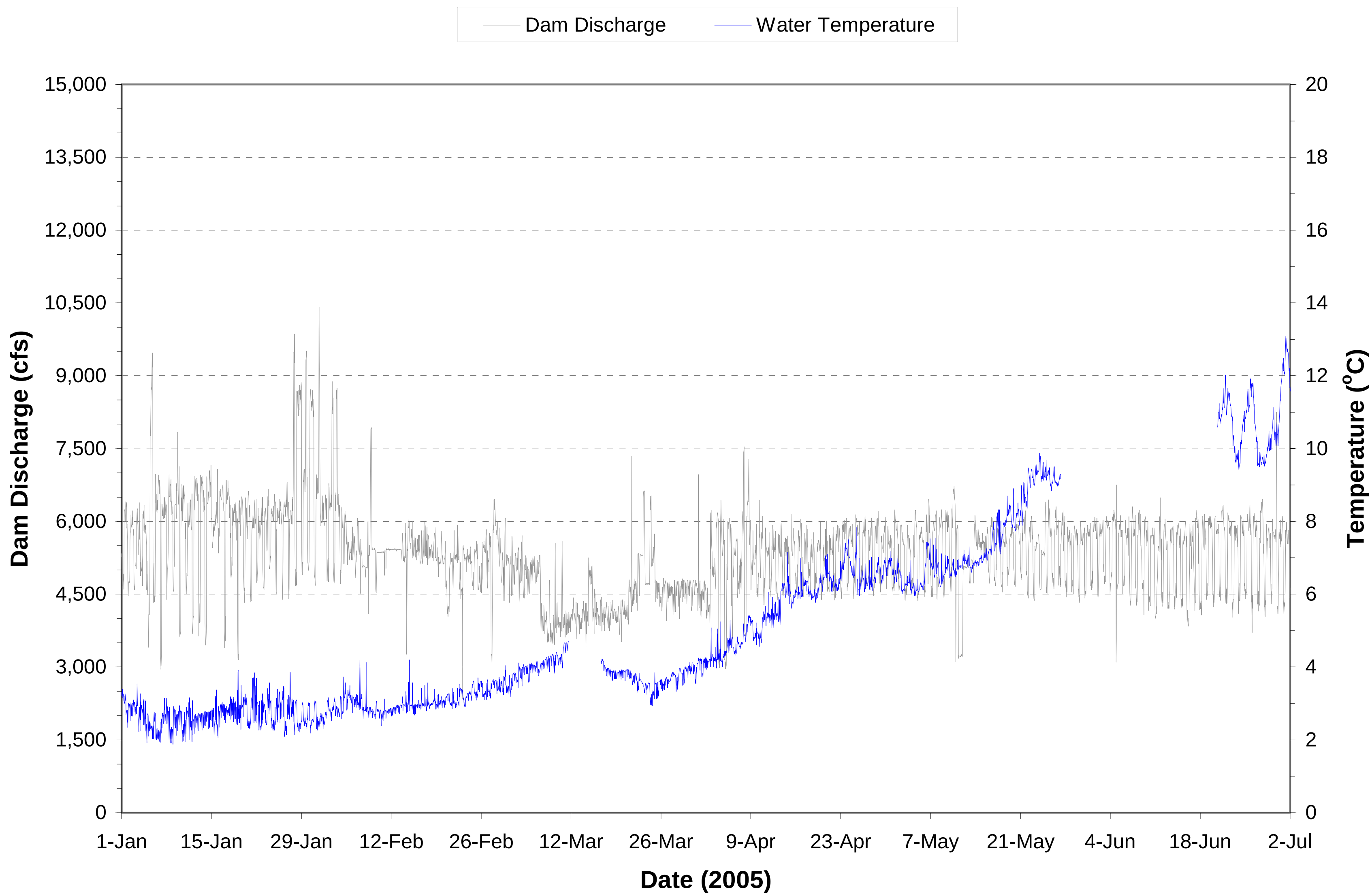


Plate 35. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2005.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

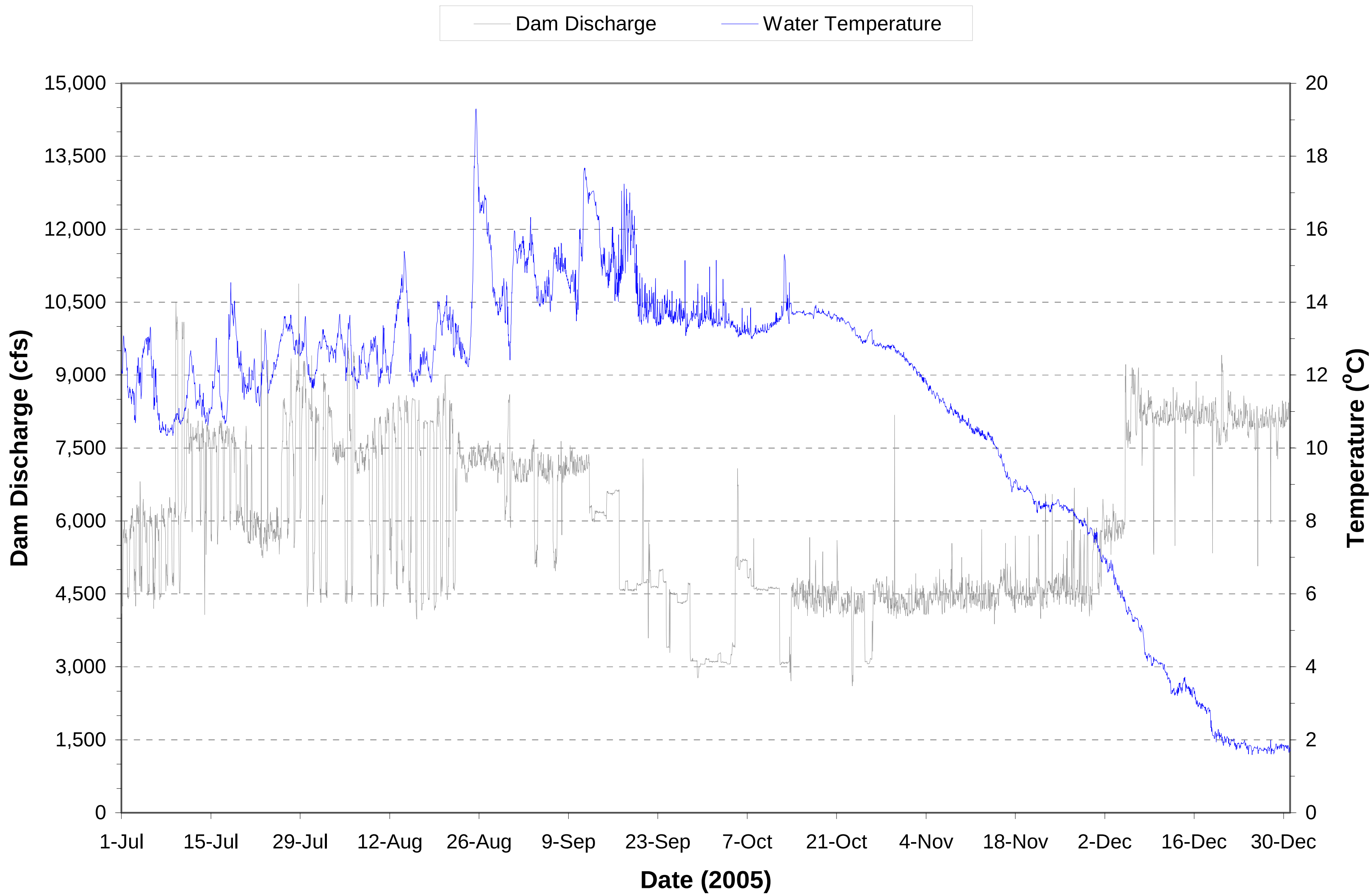


Plate 36. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2005.

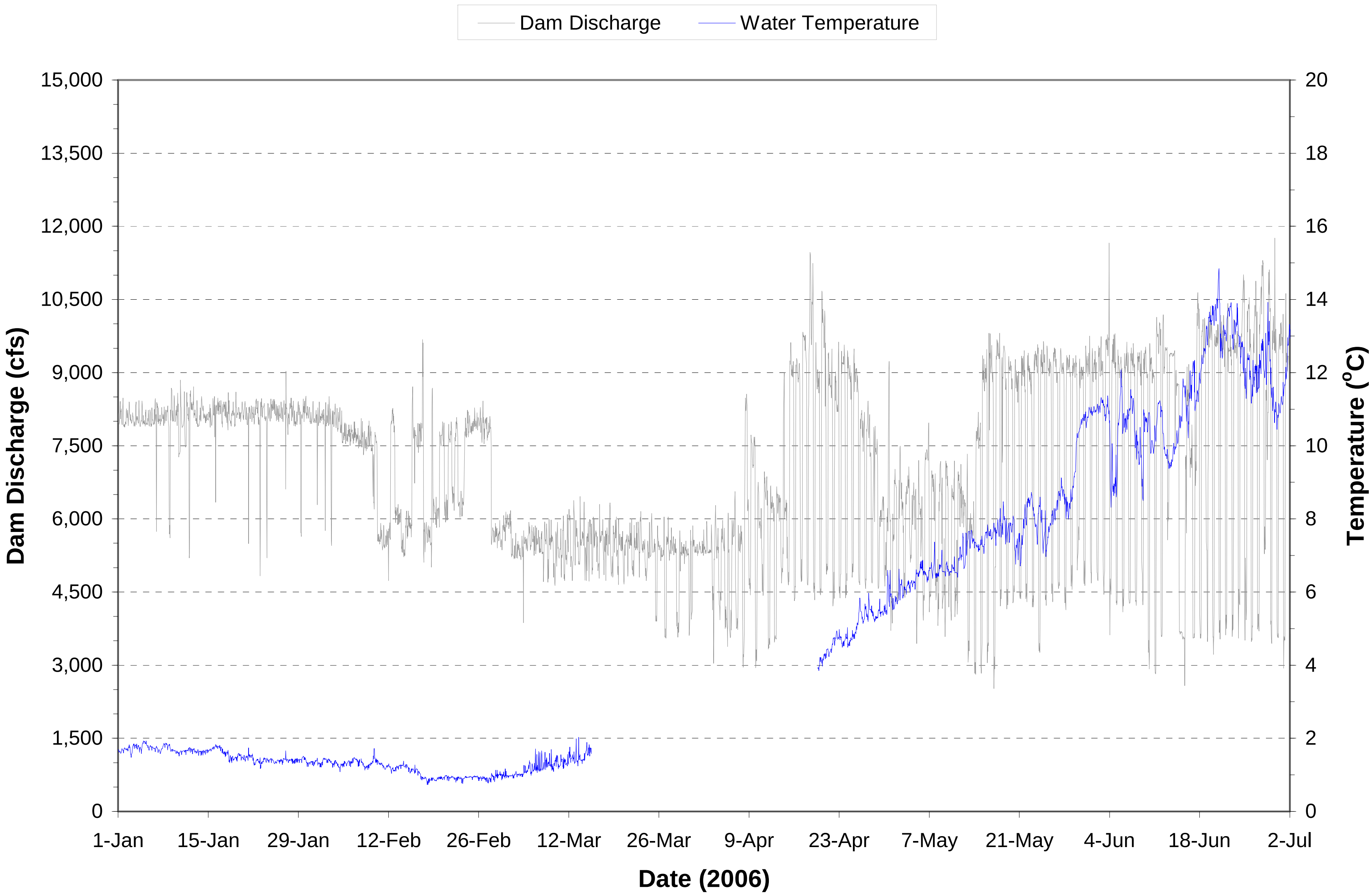


Plate 37. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

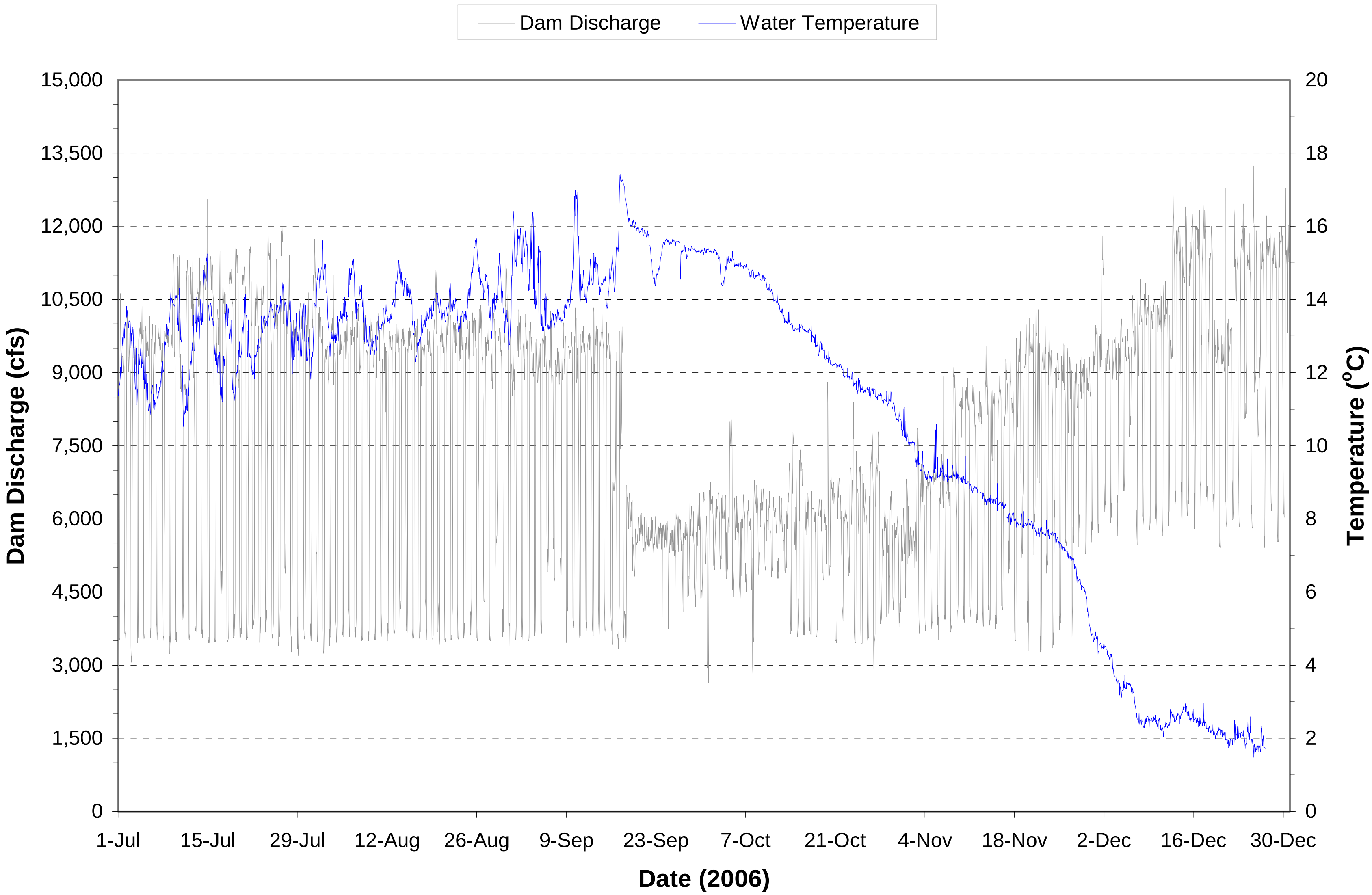


Plate 38. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

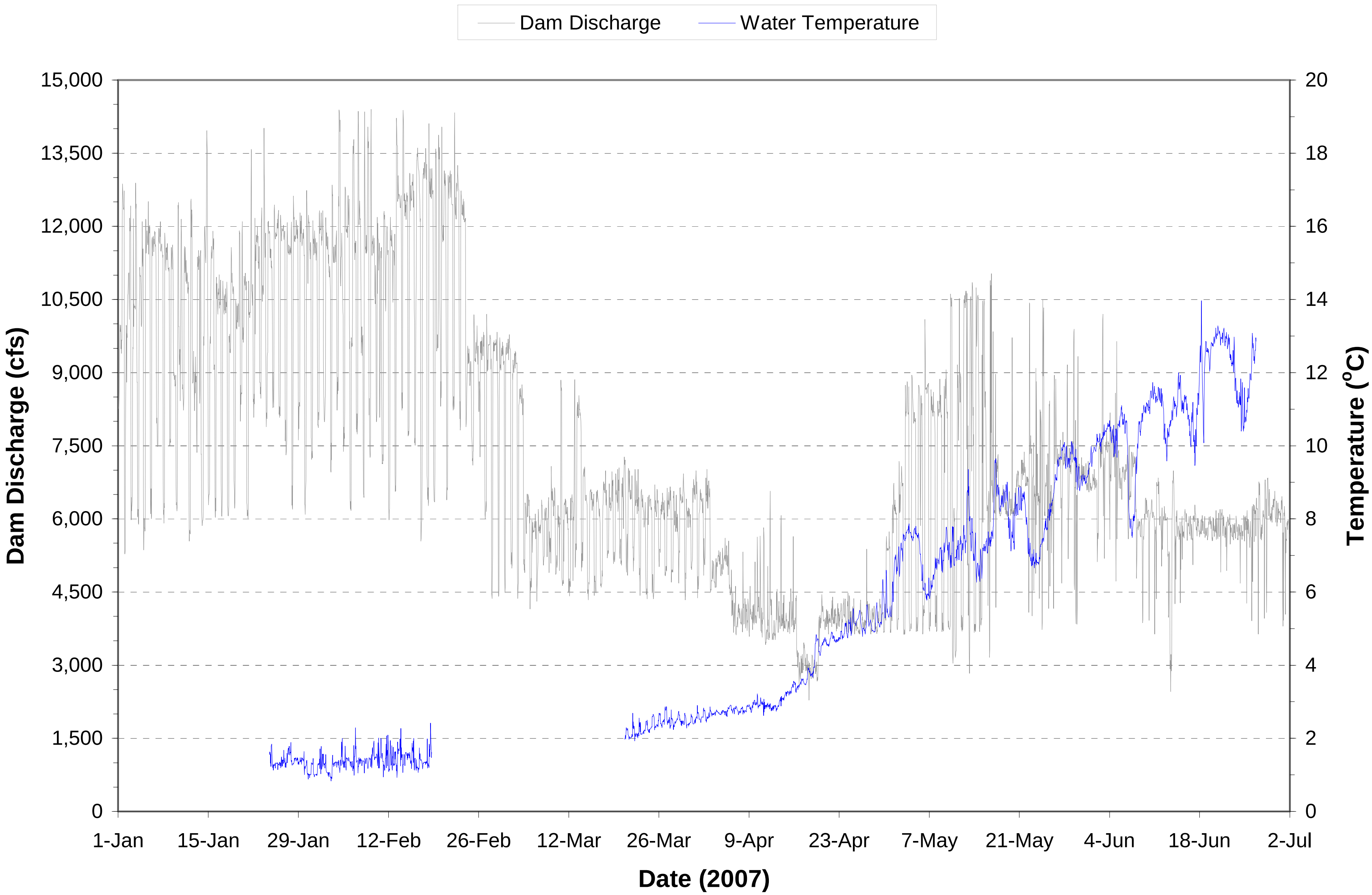


Plate 39. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2007.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

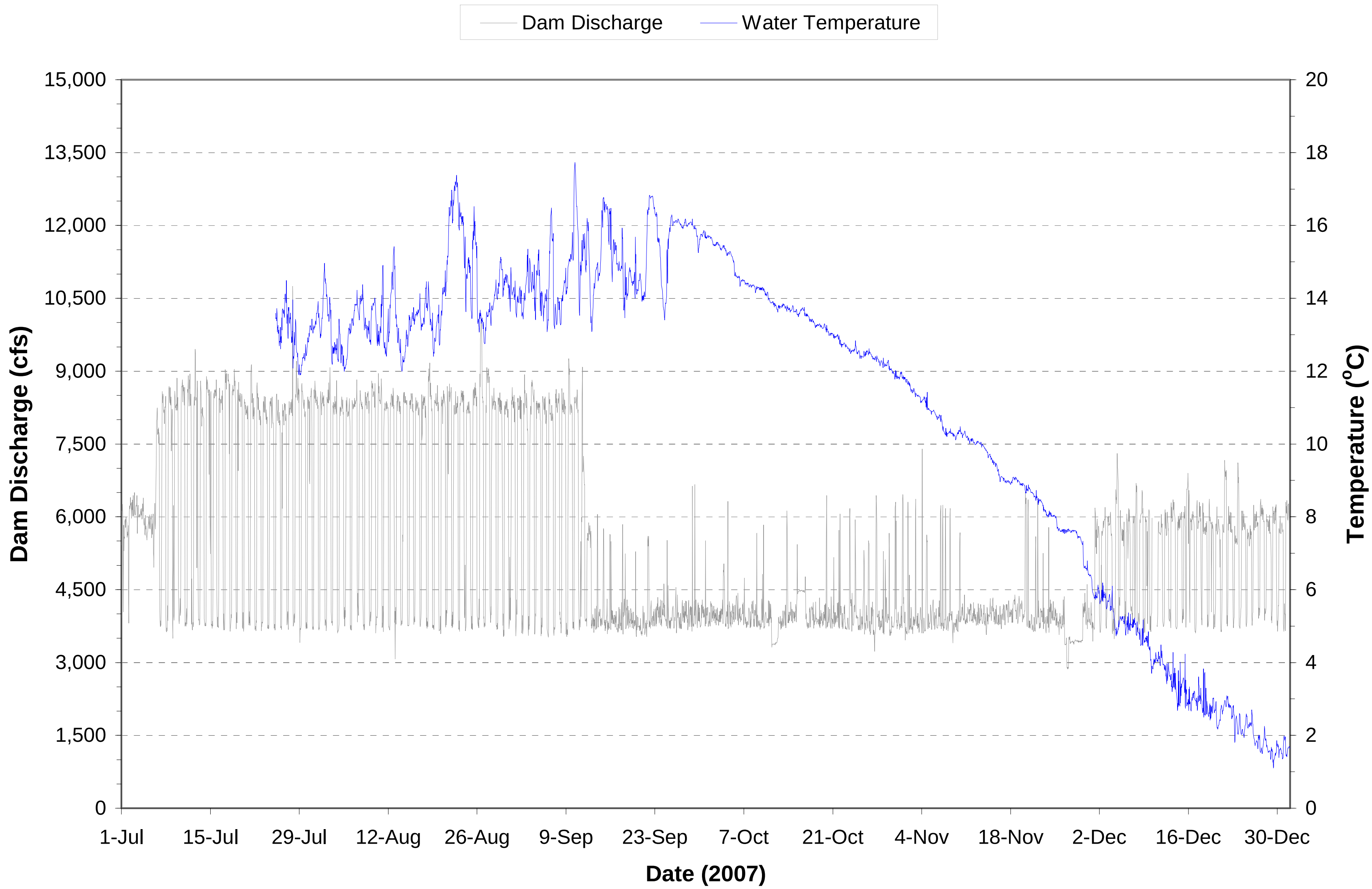


Plate 40. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

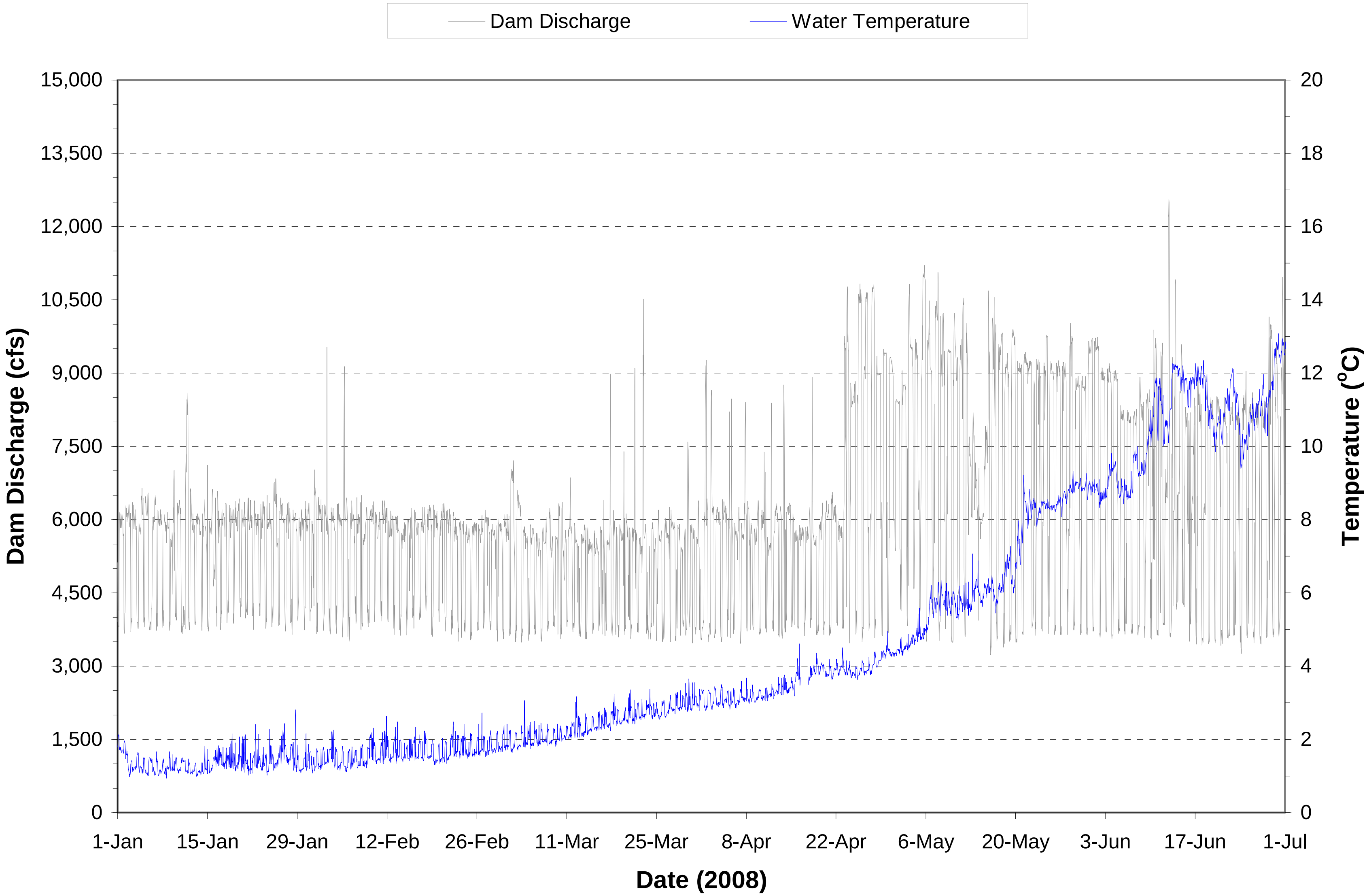


Plate 41. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2008.

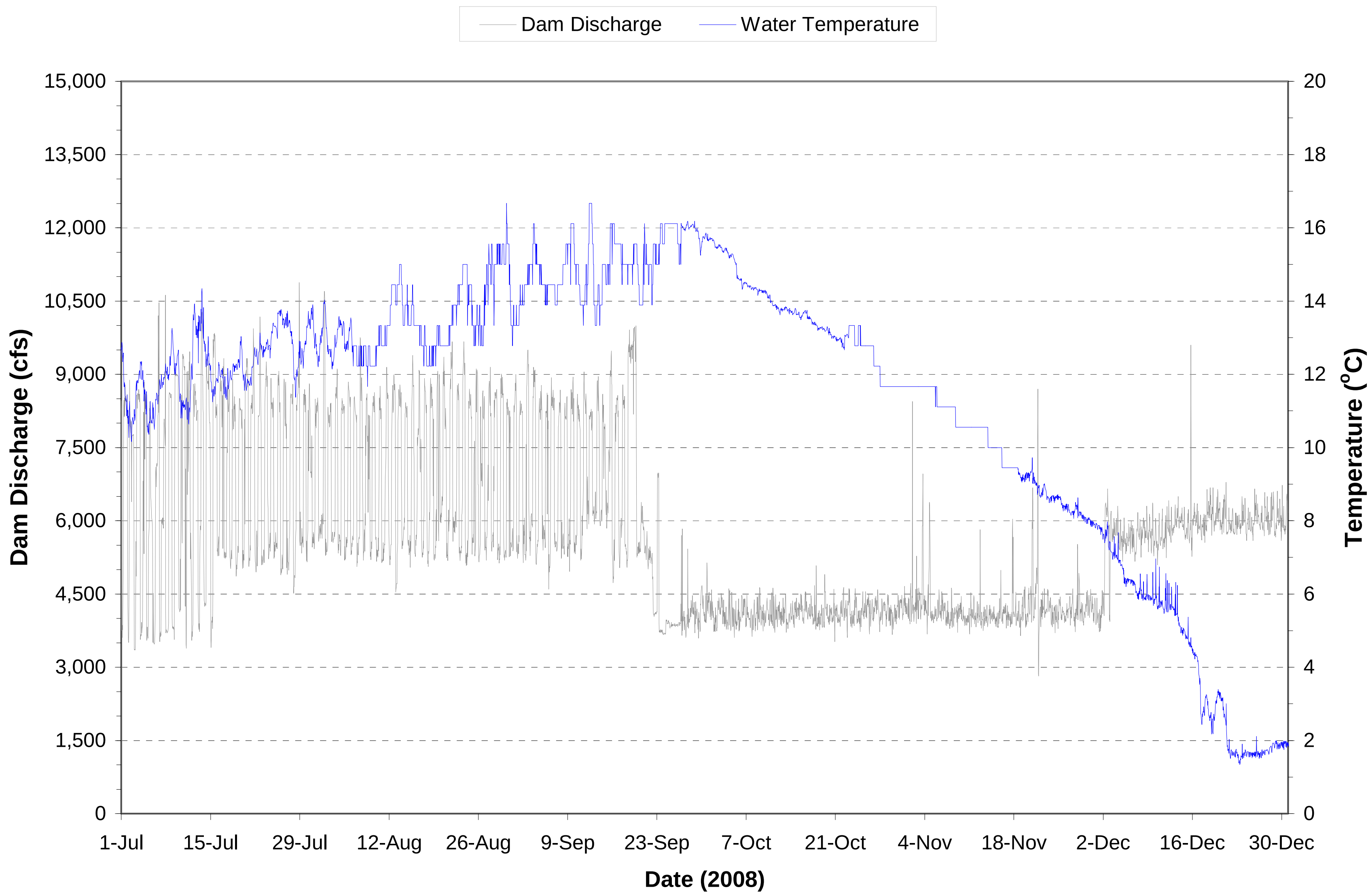


Plate 42. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2008.

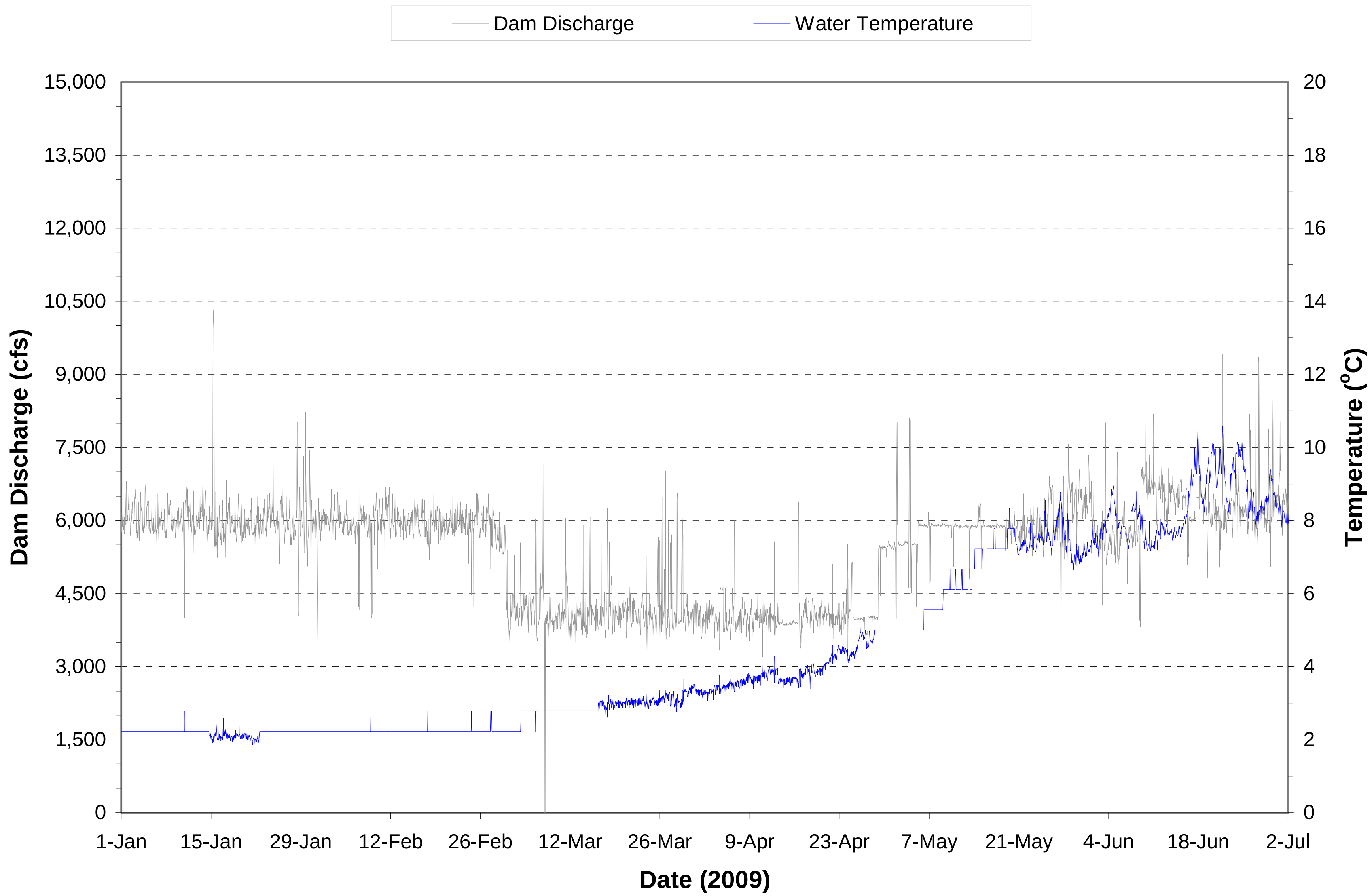


Plate 43. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2009.

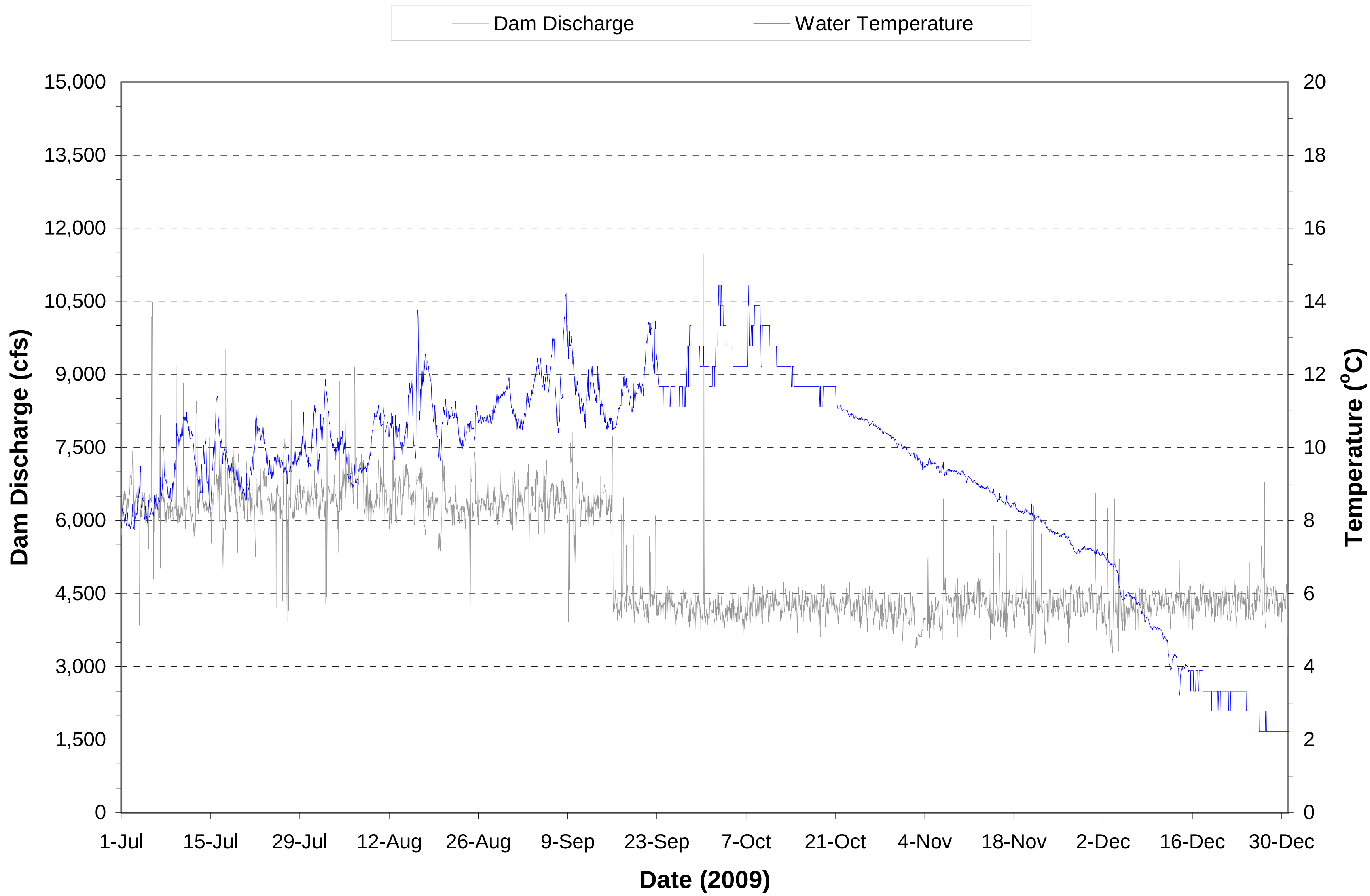


Plate 44. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2009.

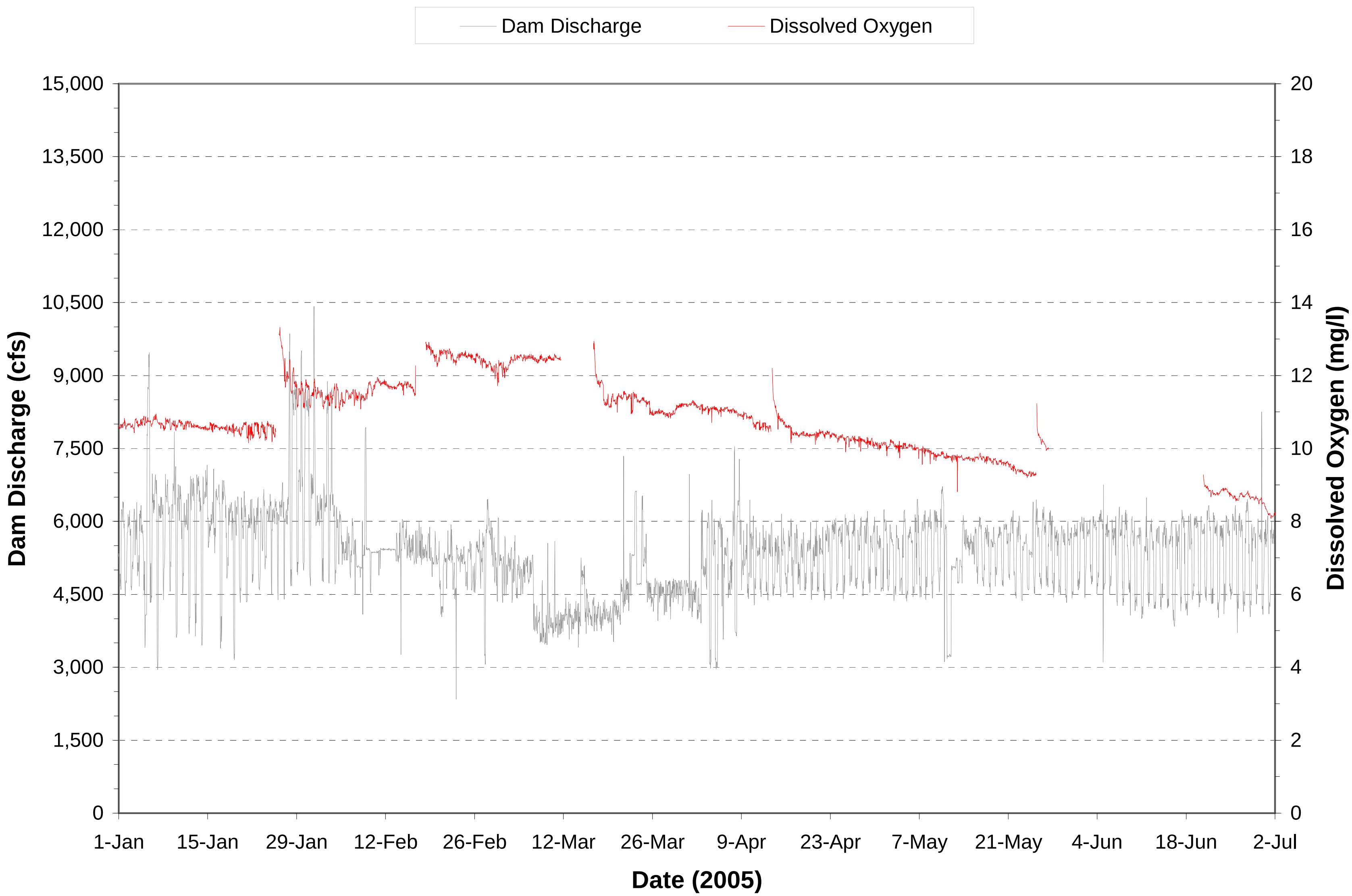


Plate 45. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2005.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

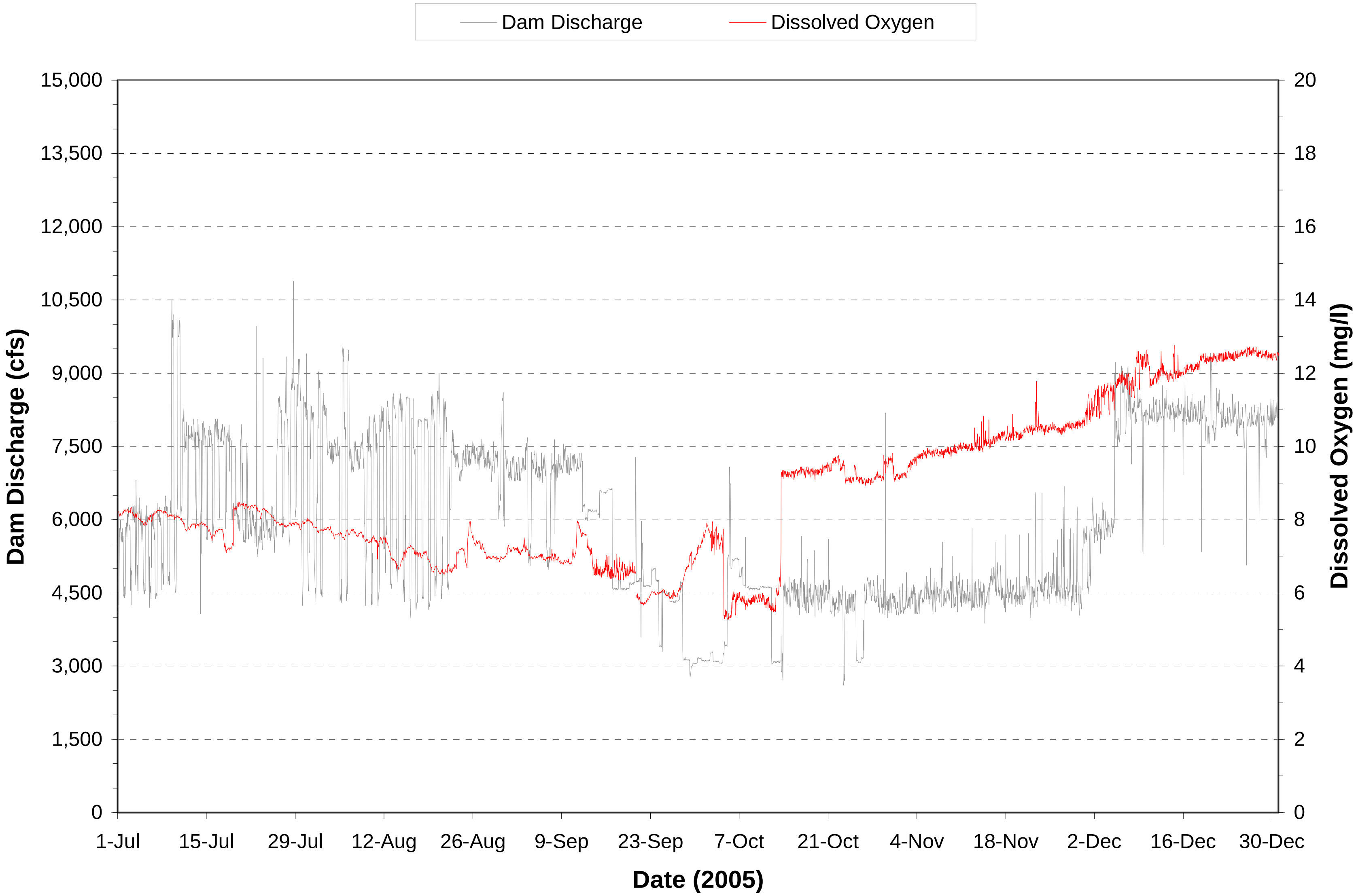


Plate 46. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2005.

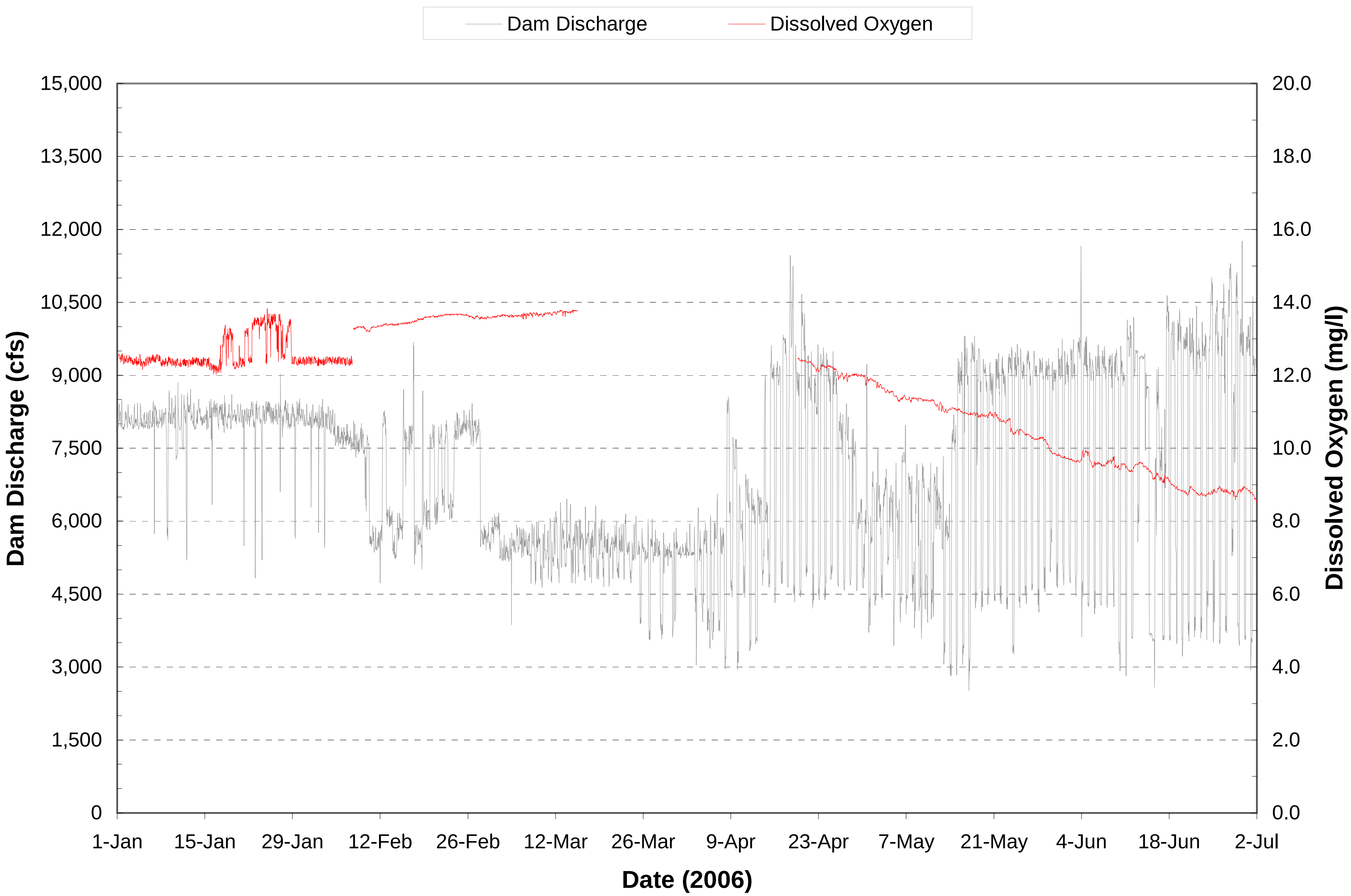


Plate 47. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

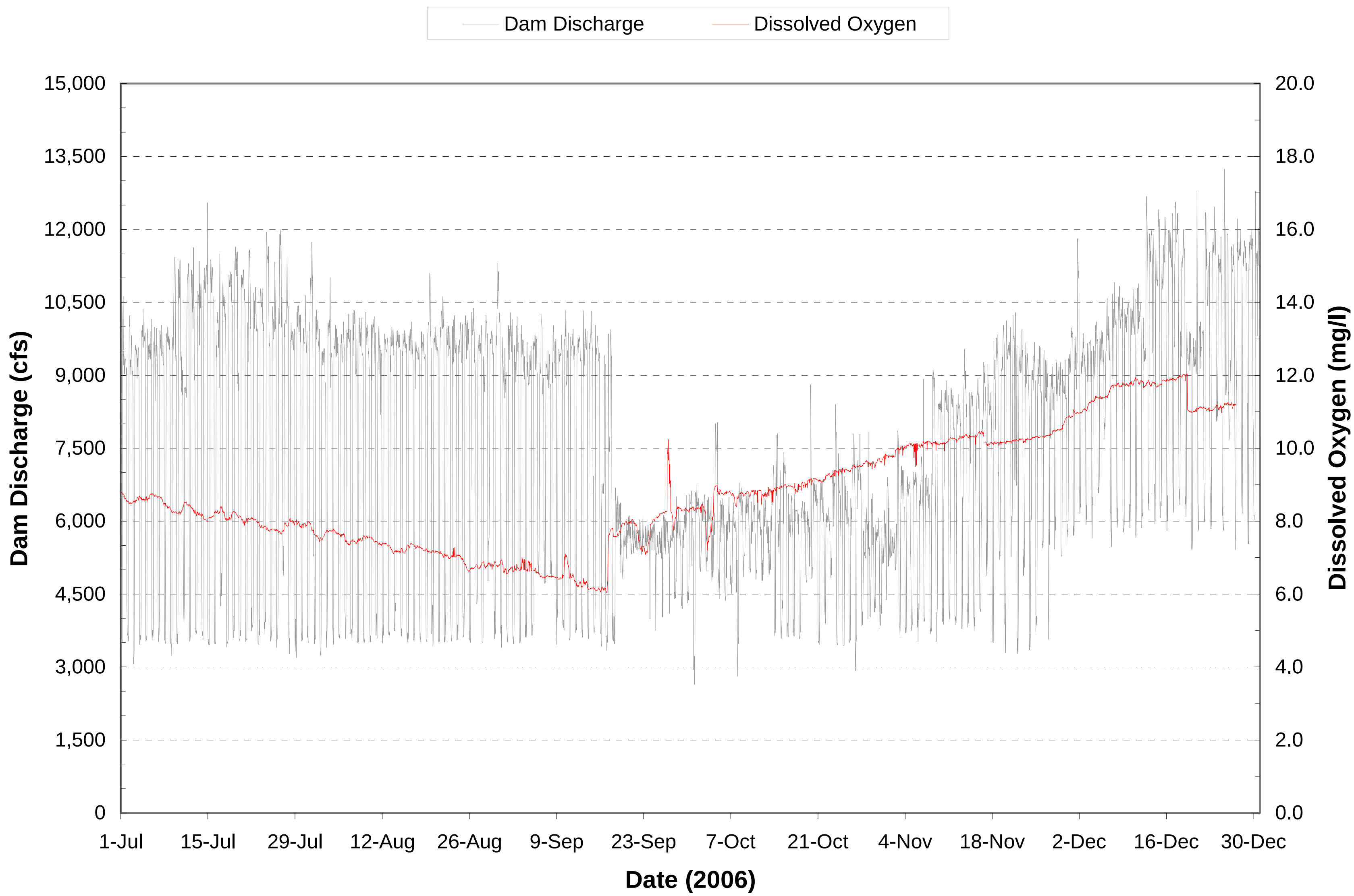


Plate 48. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2006.

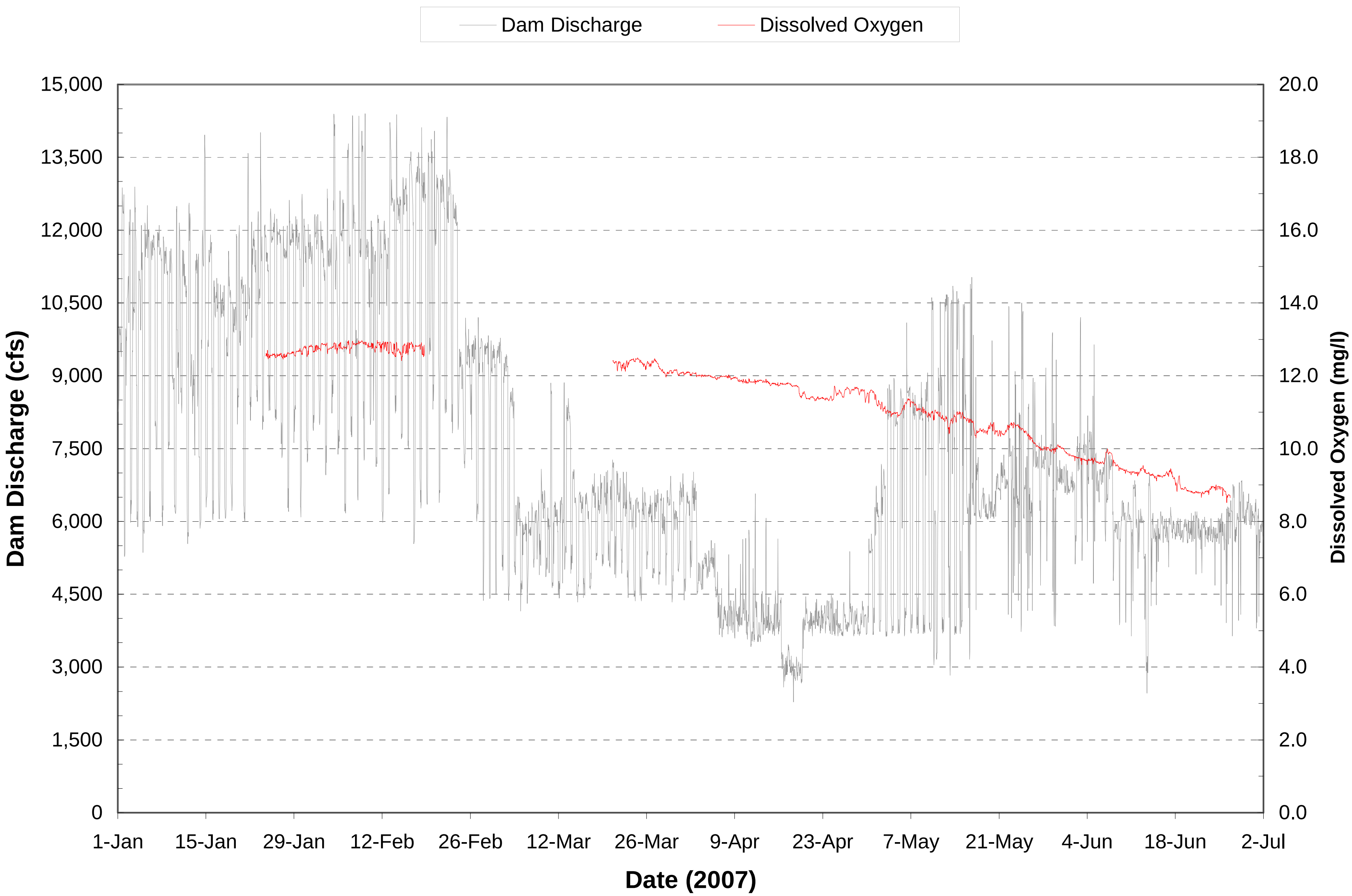


Plate 49. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2007.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

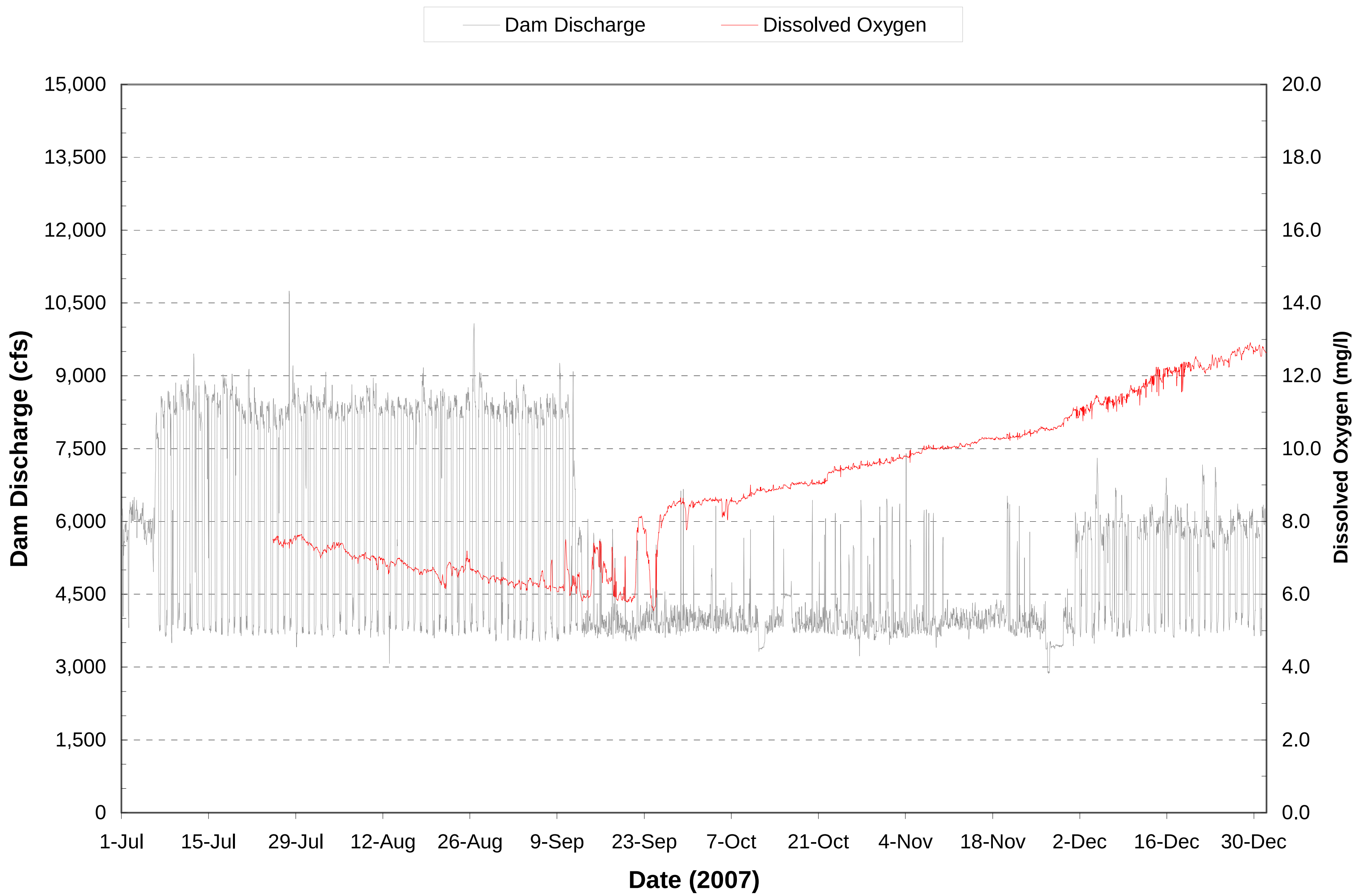


Plate 50. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

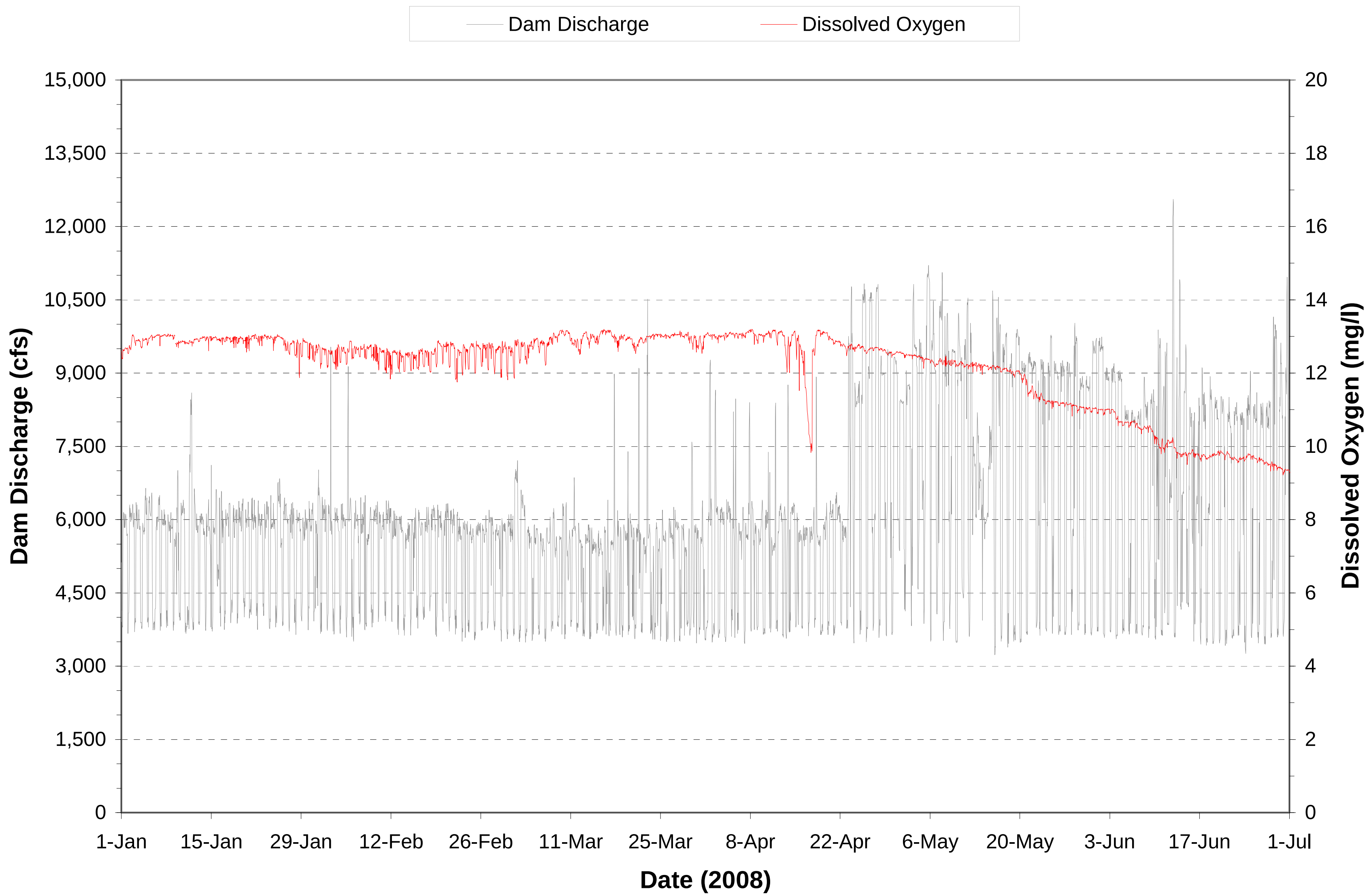


Plate 51. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2008.

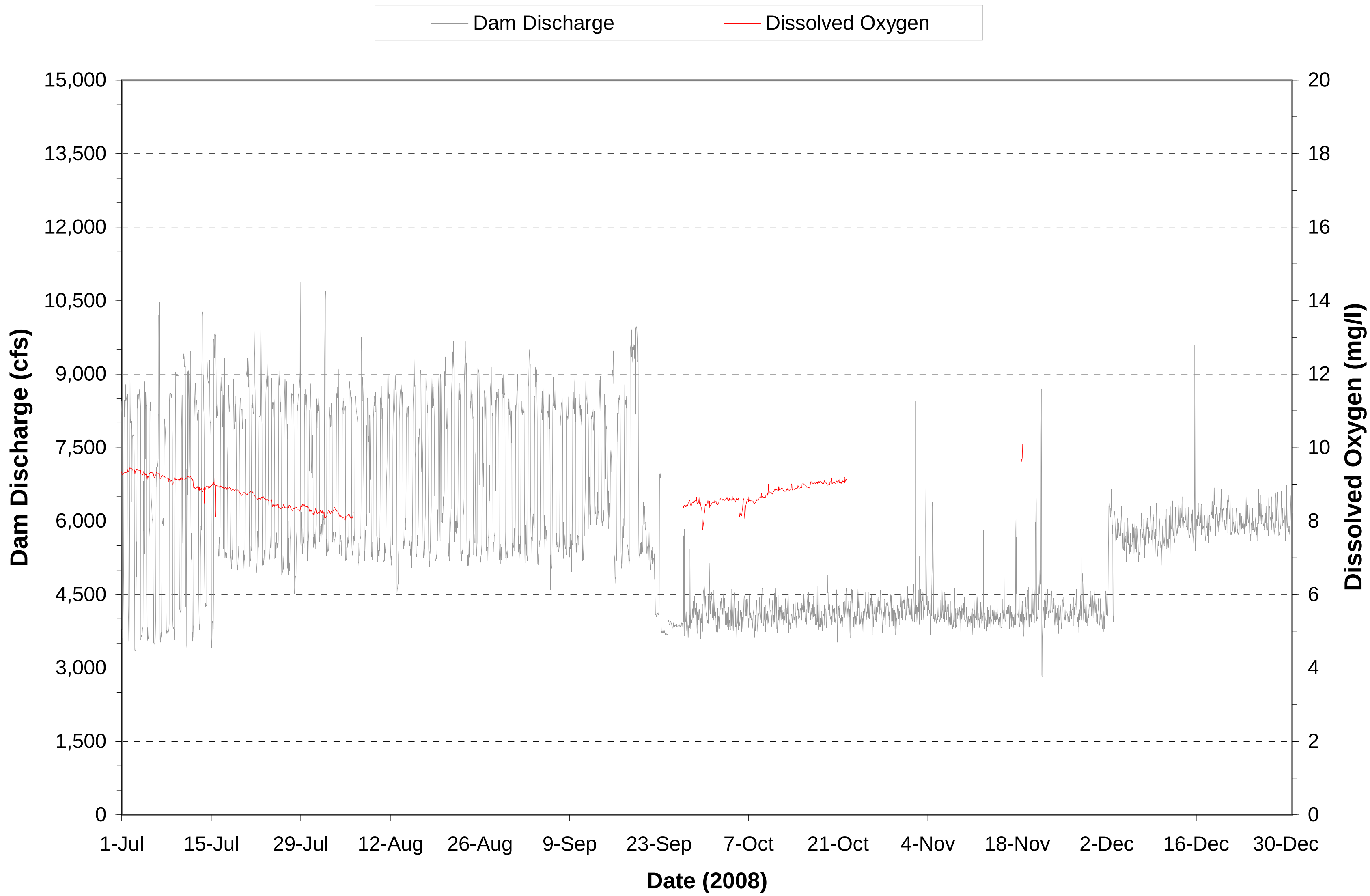


Plate 52. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2008.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

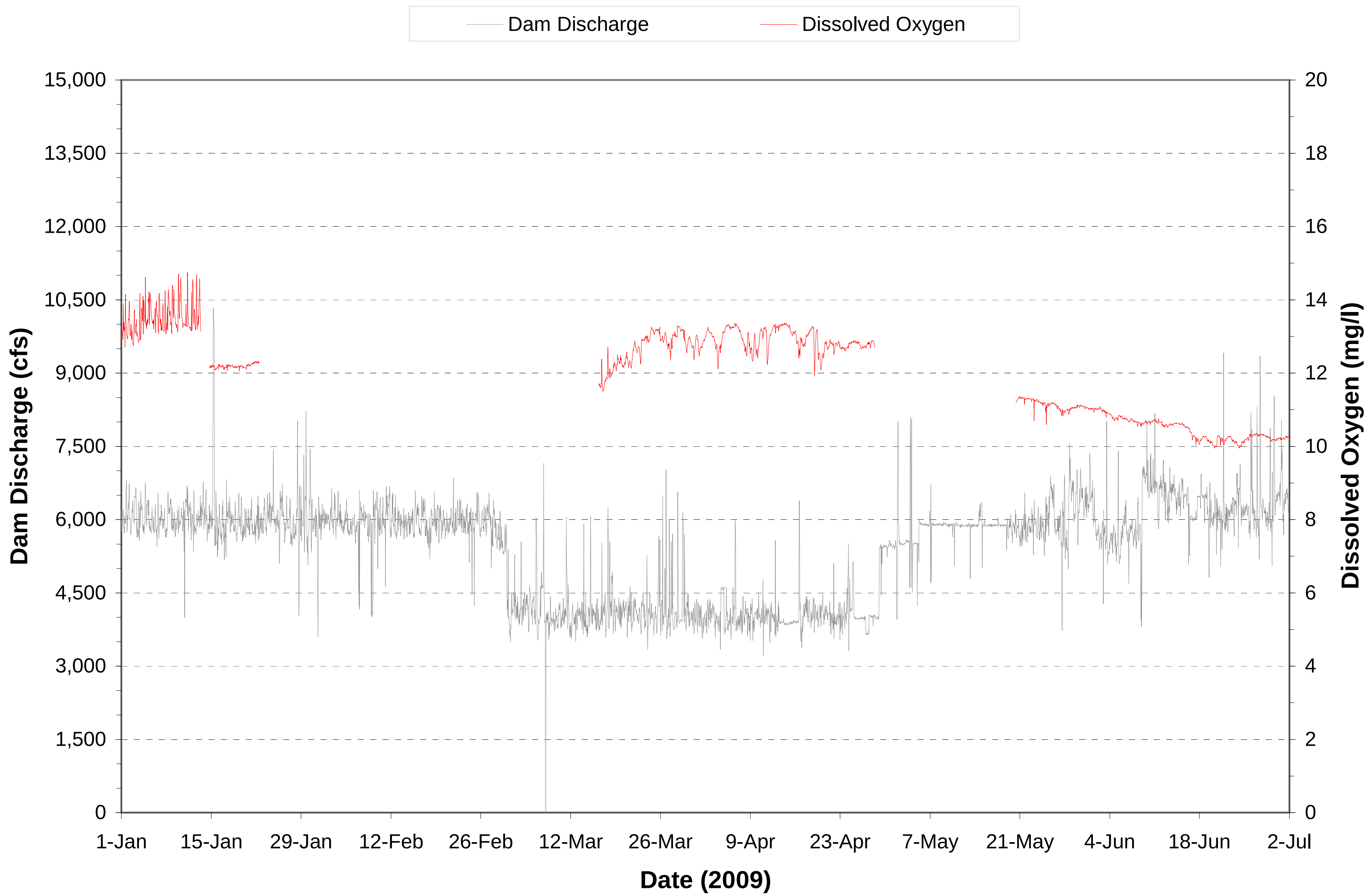


Plate 53. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2009.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

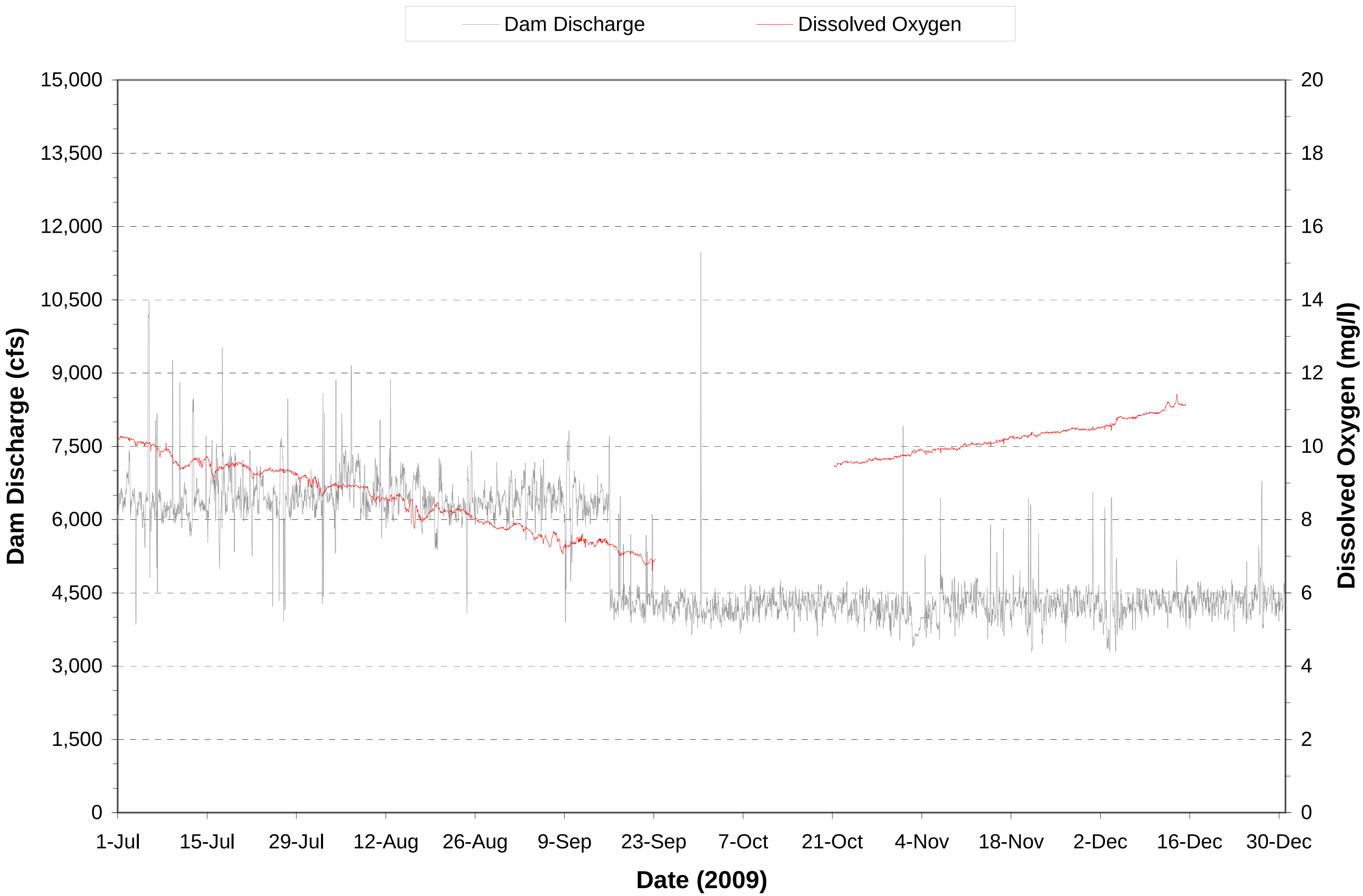


Plate 54. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2008.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

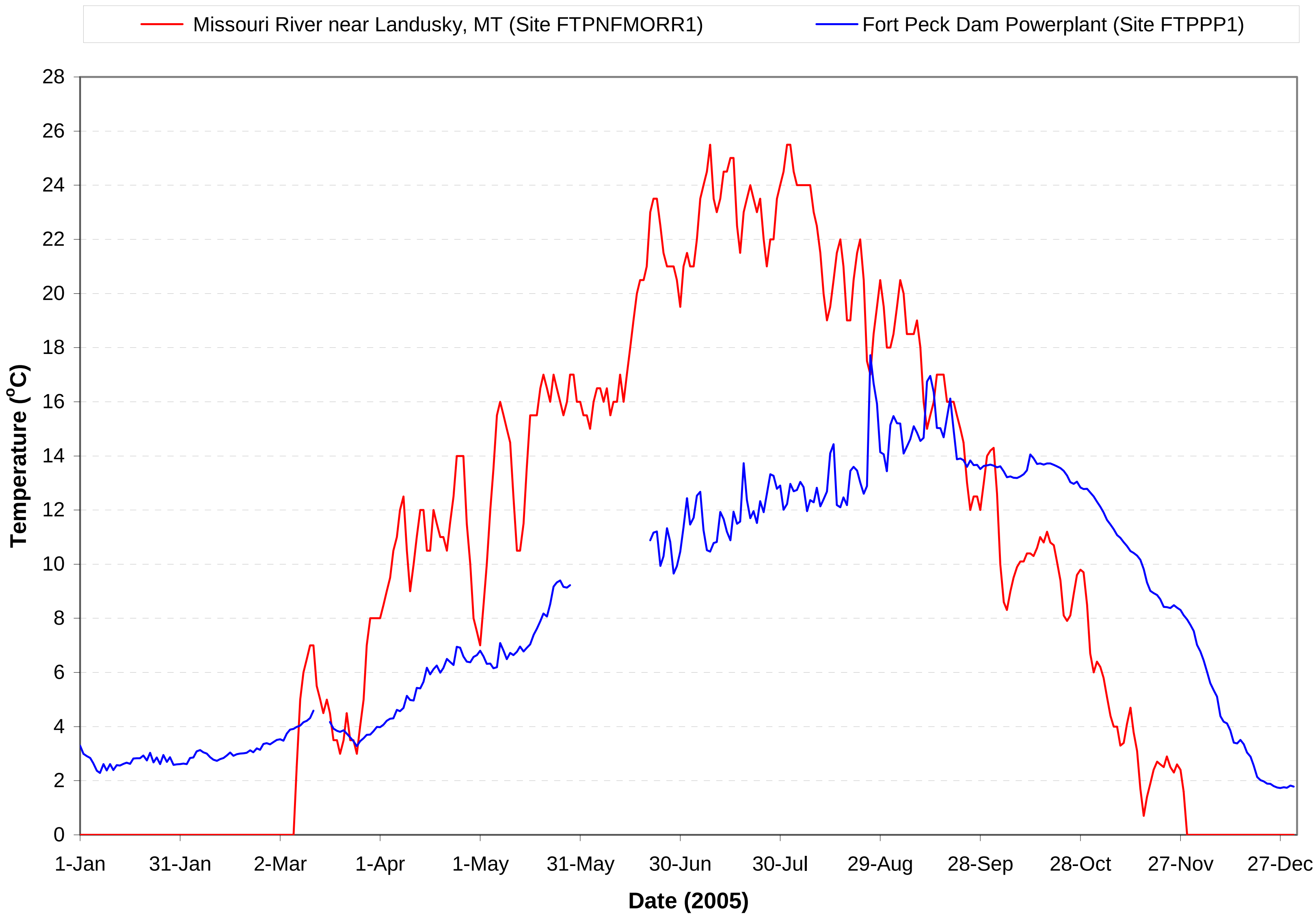


Plate 55. Mean daily water temperatures monitored at the Fort Peck Powerplant (i.e., site FTPPP1) and the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) during 2005.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

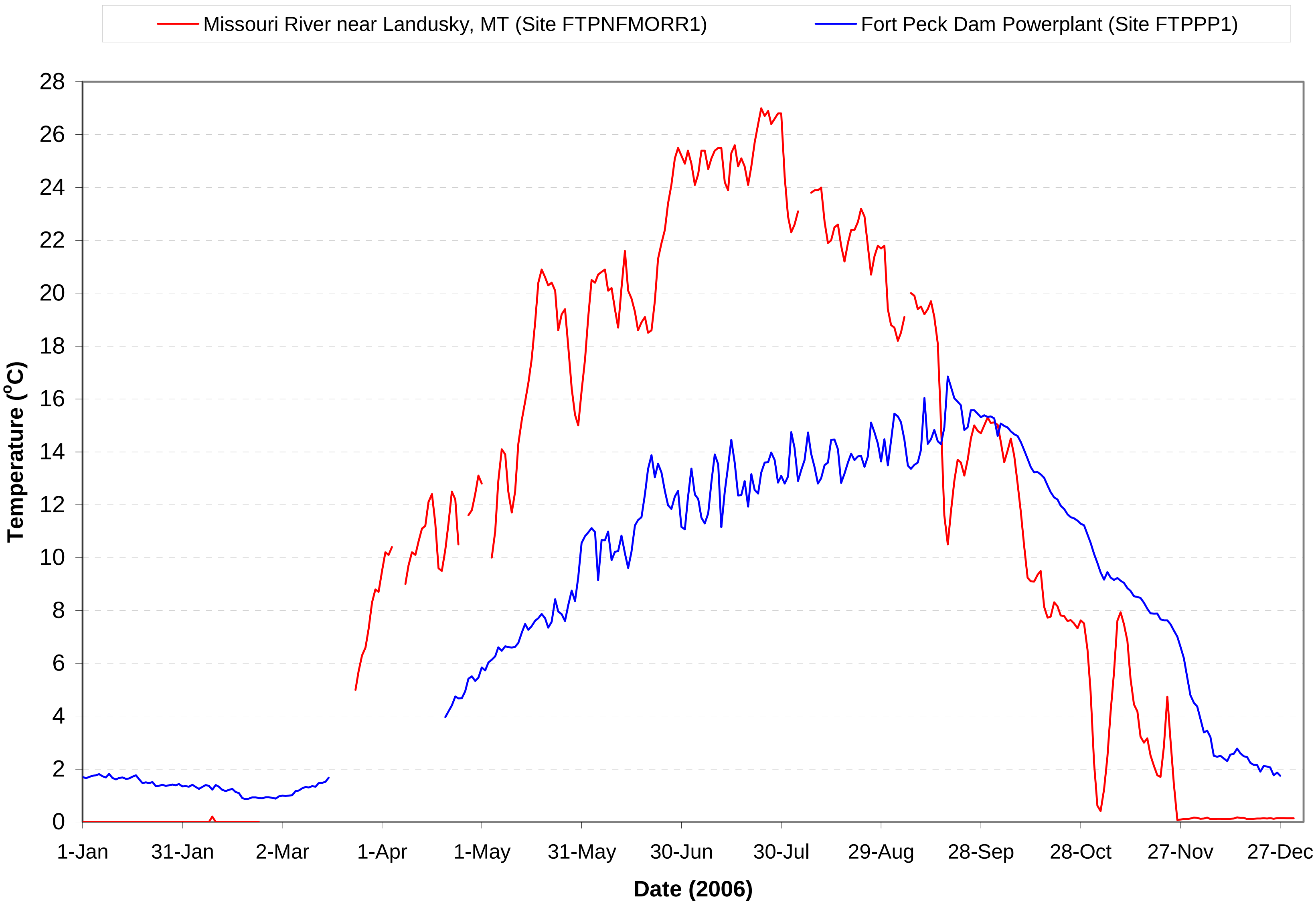


Plate 56. Mean daily water temperatures monitored at the Fort Peck Powerplant (i.e., site FTPPP1) and the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) during 2006.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

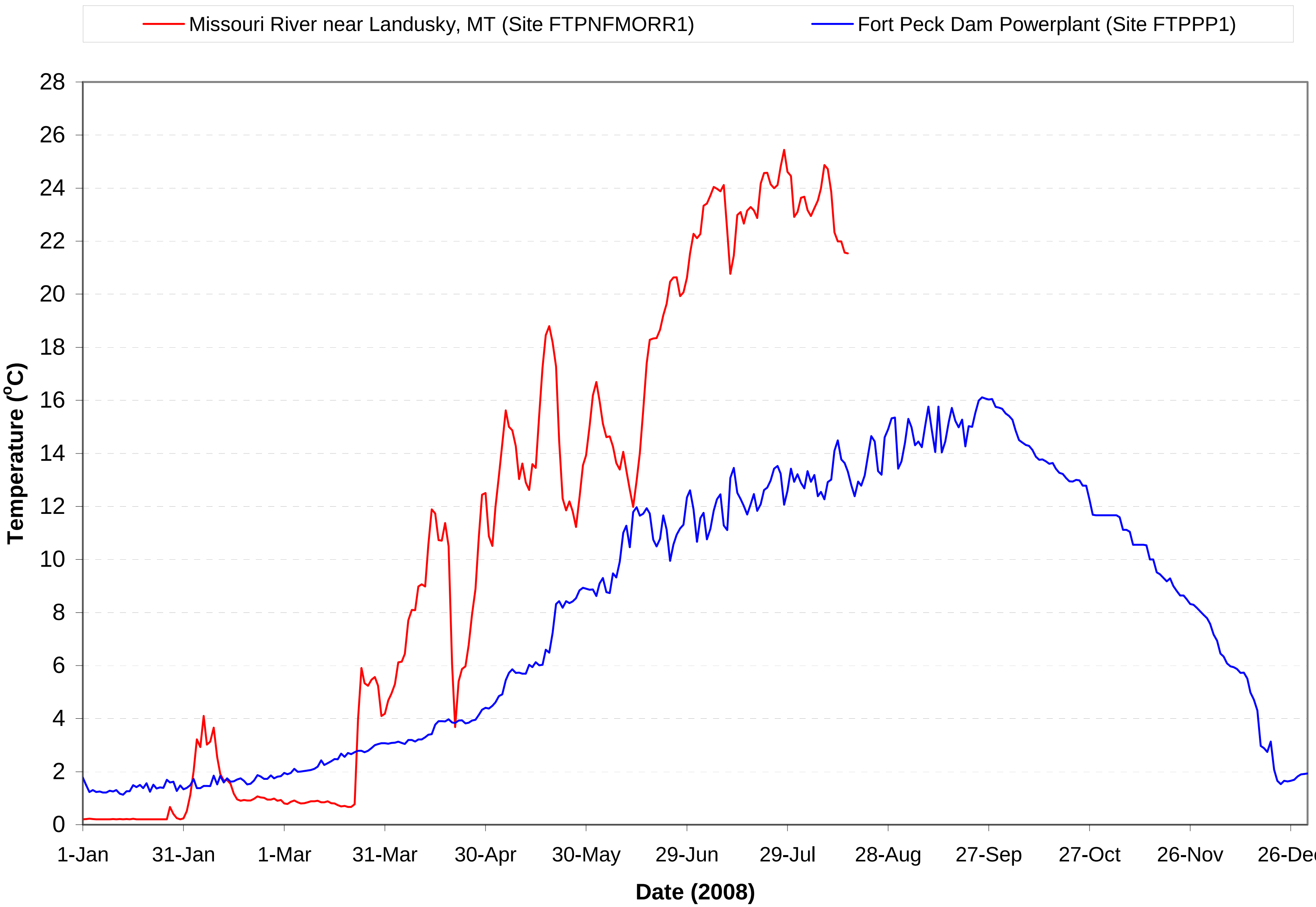


Plate 57. Mean daily water temperatures monitored at the Fort Peck Powerplant (i.e., site FTPPP1) and the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) during 2008.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

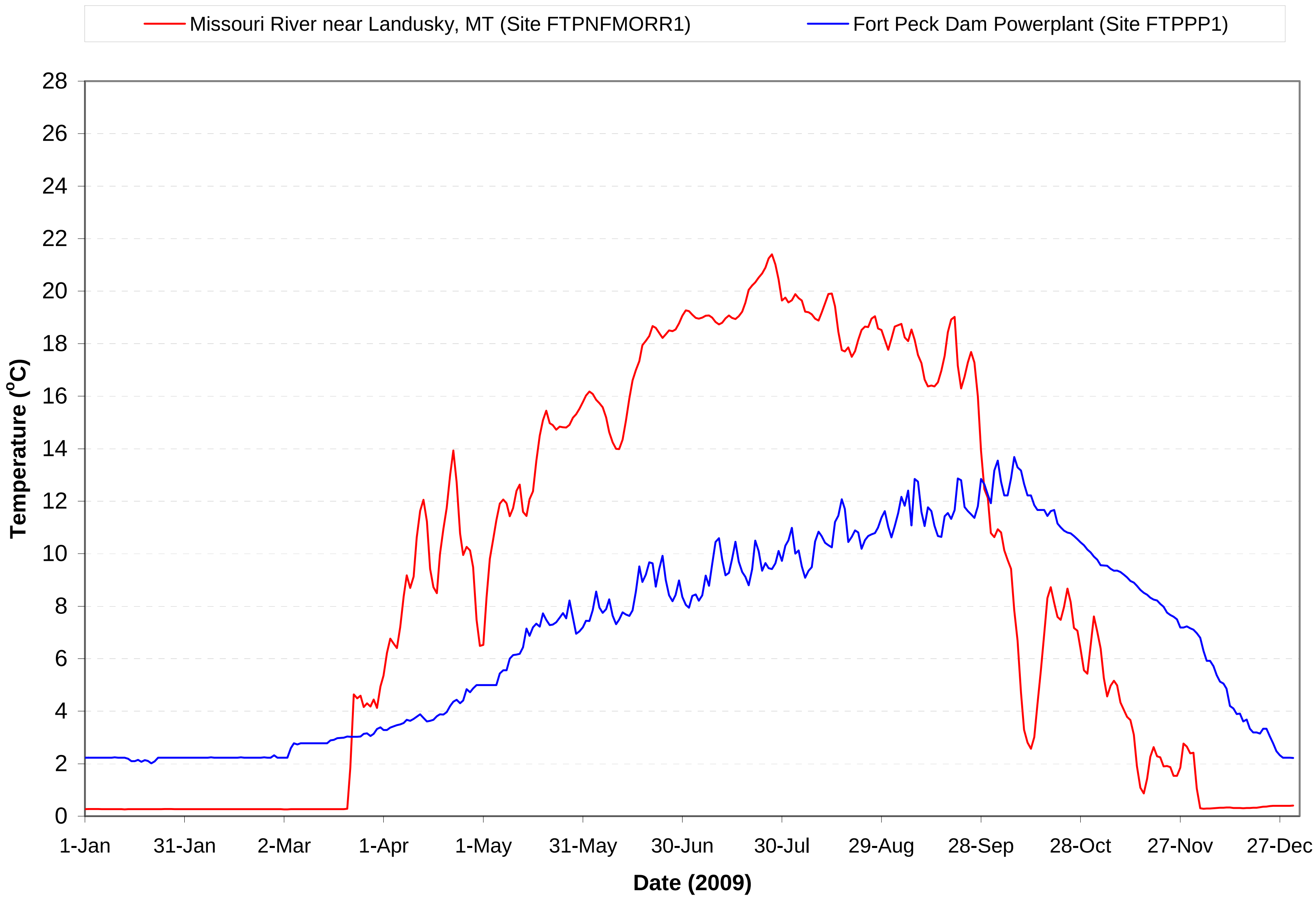


Plate 58. Mean daily water temperatures monitored at the Fort Peck Powerplant (i.e., site FTPPP1) and the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) during 2009.

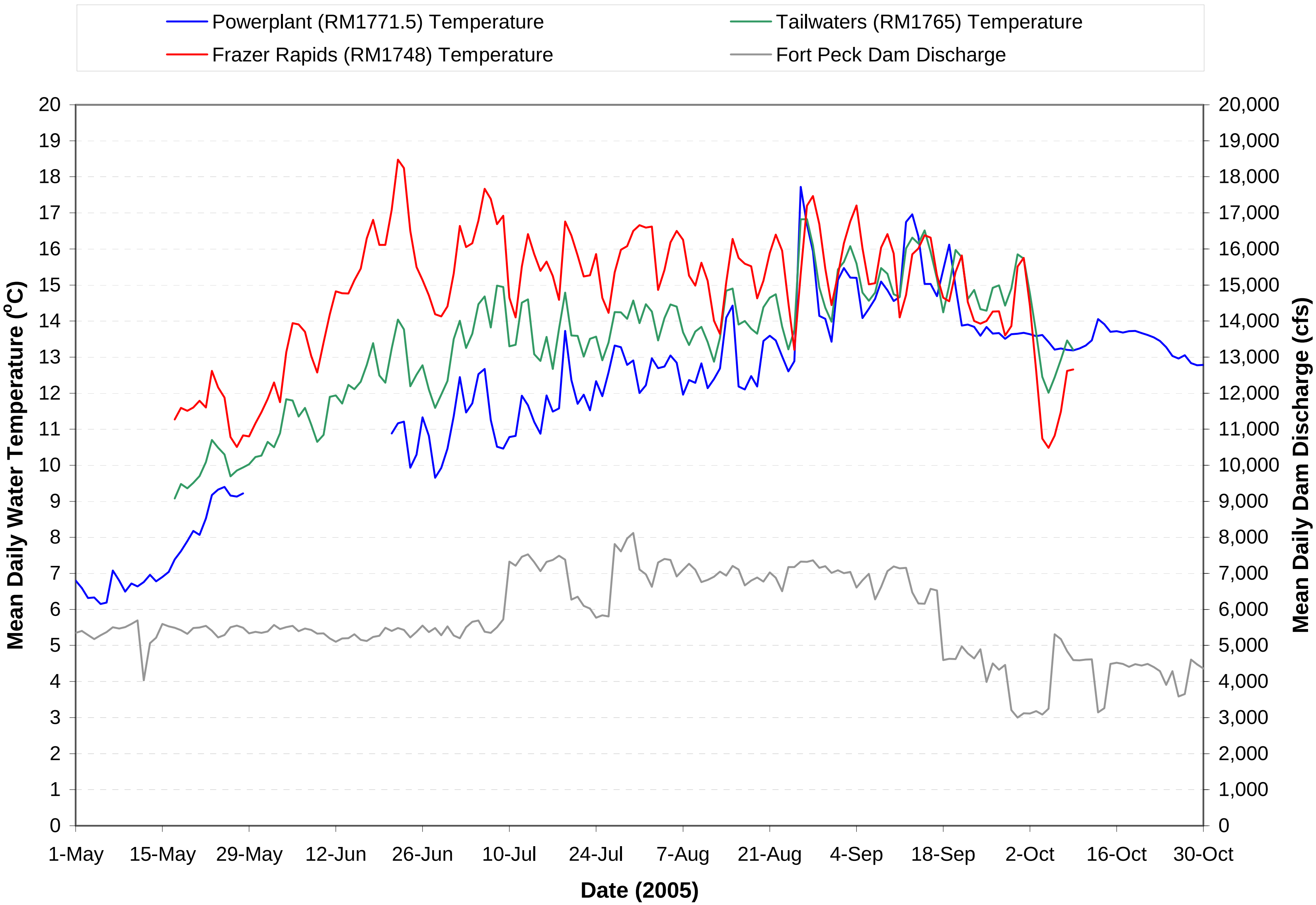


Plate 59. Mean daily water temperature monitored at the Fort Peck powerplant, Missouri River tailwaters, and Missouri River Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2005.

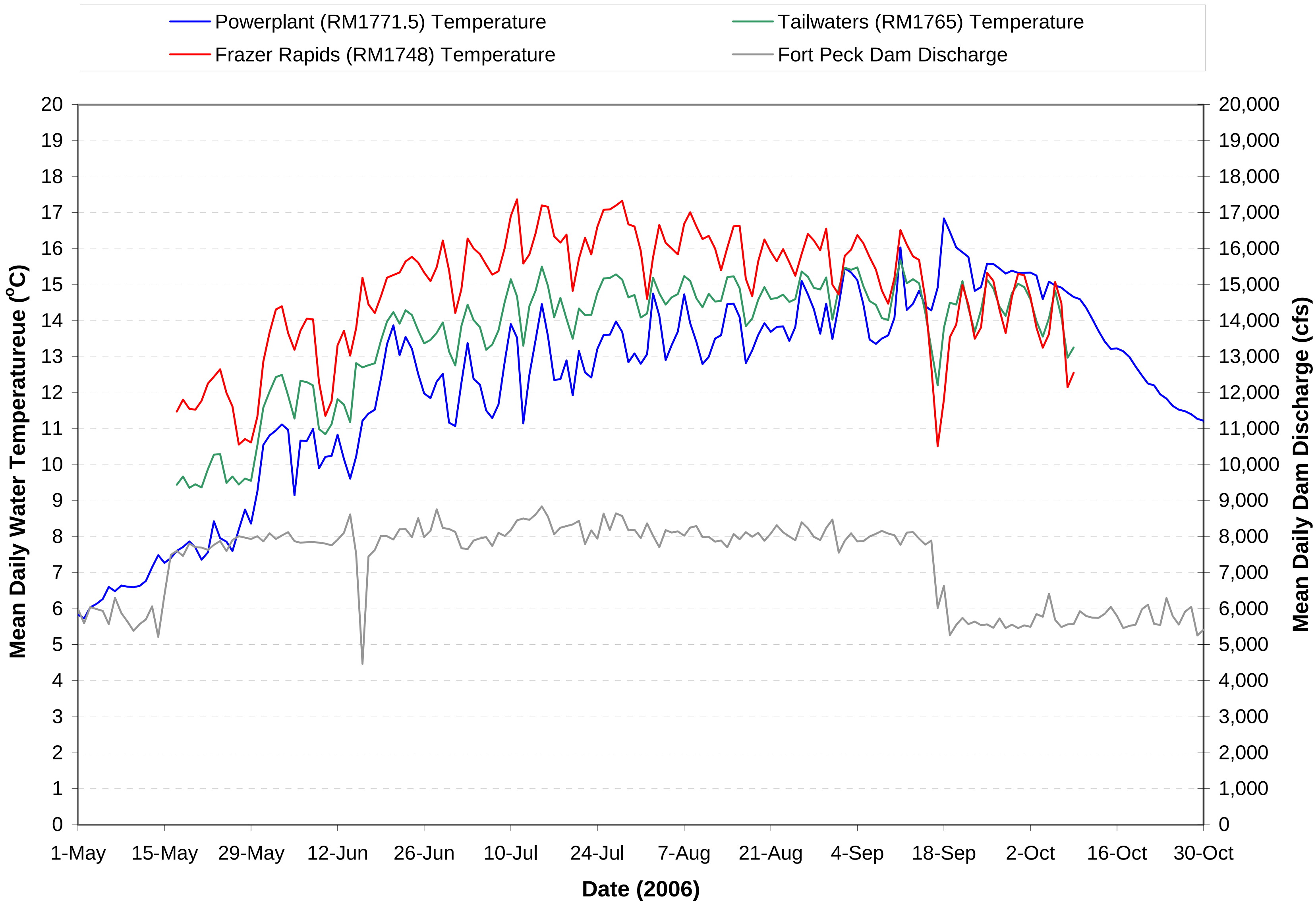


Plate 60. Mean daily water temperature monitored at the Fort Peck powerplant, Missouri River tailwaters, and Missouri River Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2006.

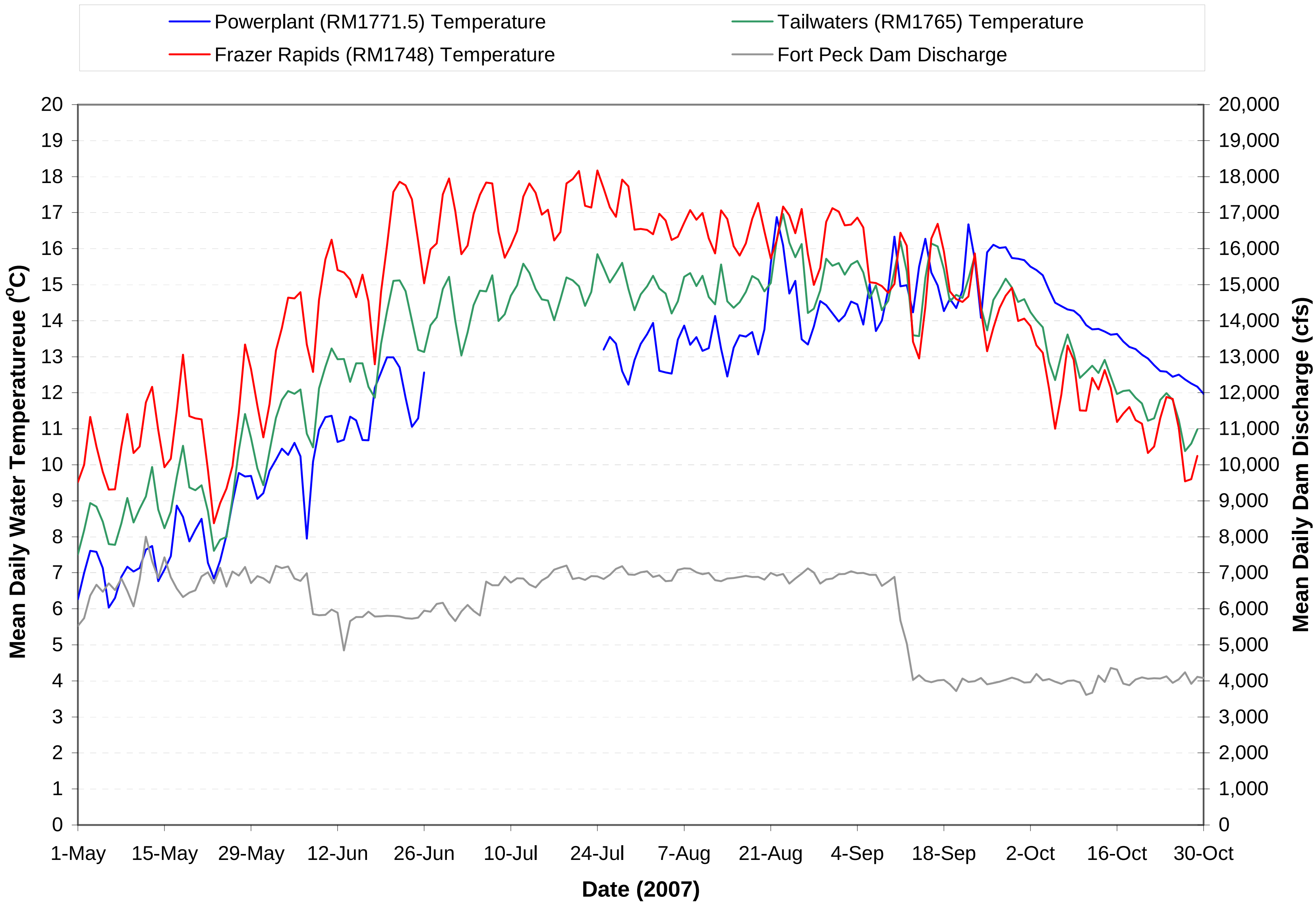


Plate 61. Mean daily water temperature monitored at the Fort Peck powerplant, Missouri River tailwaters, and Missouri River Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2007.

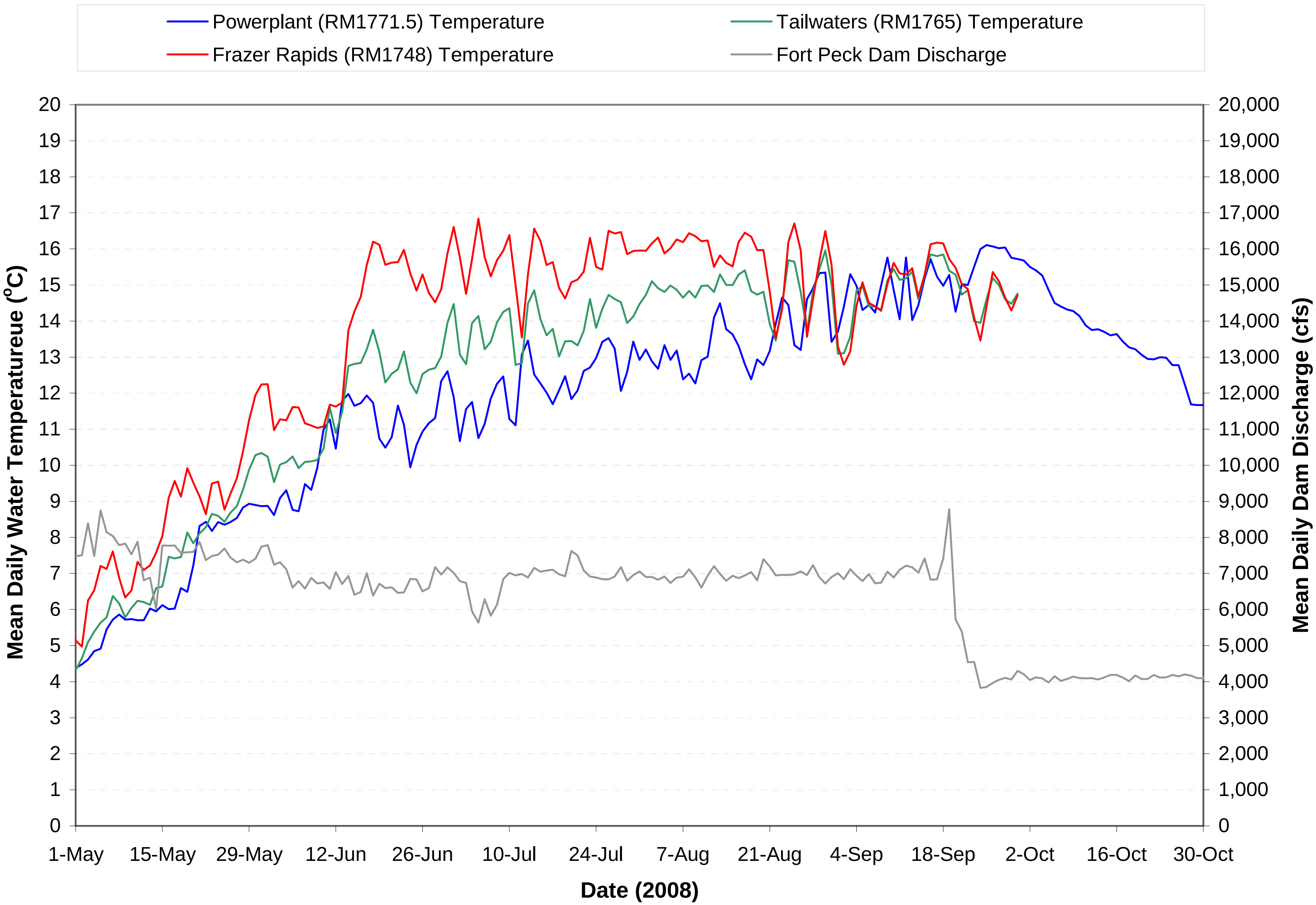


Plate 62. Mean daily water temperature monitored at the Fort Peck powerplant, Missouri River tailwaters, and Missouri River Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2008.

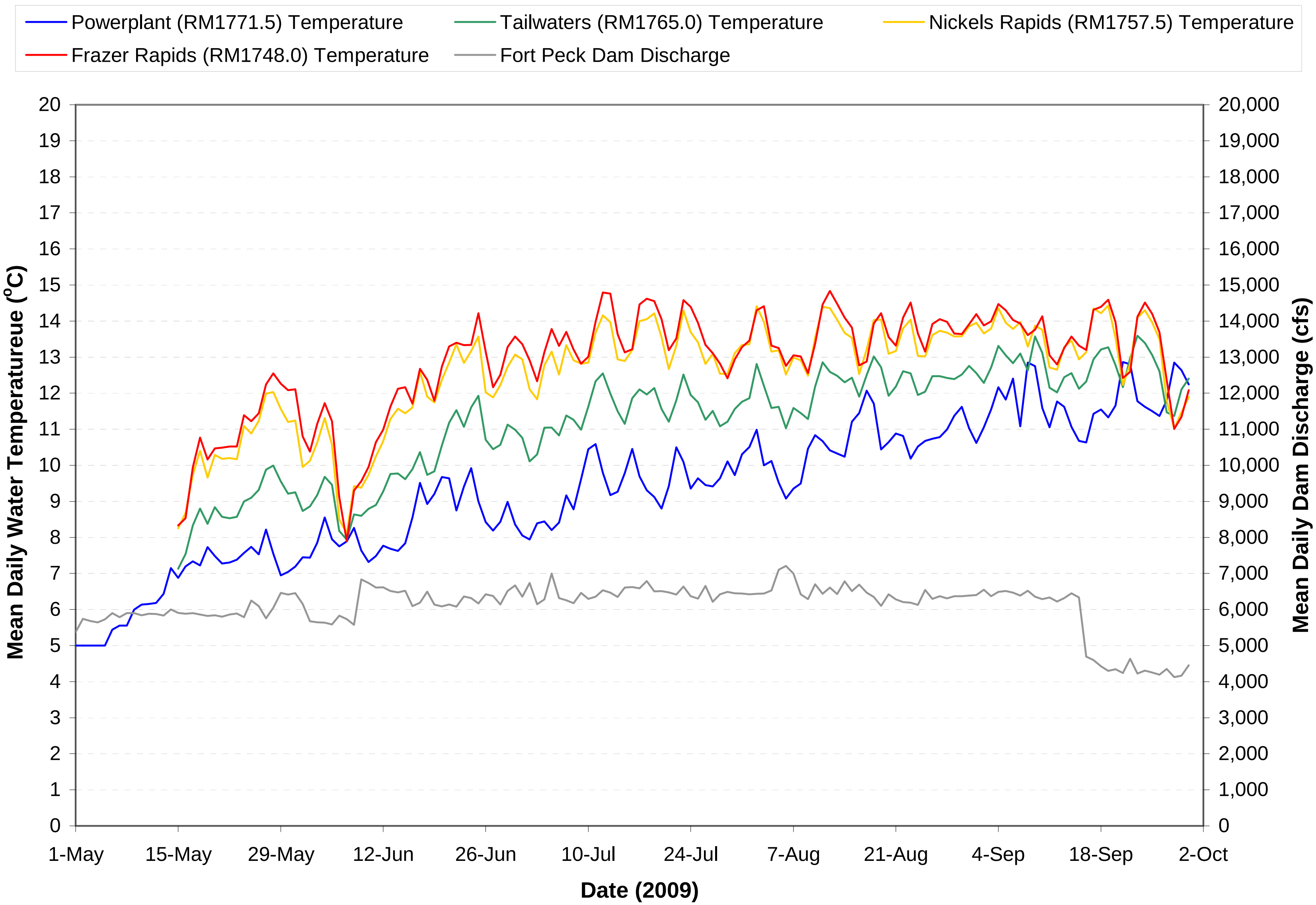


Plate 63. Mean daily water temperature monitored at the Fort Peck powerplant, Missouri River tailwaters, and Missouri River Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2009.

Plate 64. Summary of monthly (May through September) water quality conditions monitored in Lake Sakakawea near Garrison Dam (Site GARLK1390A) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	27	1819.4	1816.0	1807.3	1842.4	-----	-----	-----
Water Temperature (°C)	0.1	1,141	13.6	14.5	4.4	23.4	29.4[1,3]	0	0%
Hypolimnion Water Temperature (°C)[E]	0.1	331	11.6	11.8	5.6	17.3	15.0[2,3]	25	8%
Dissolved Oxygen (mg/l)	0.1	1,141	8.8	8.6	3.8	12.2	5[1,4]	41	4%
Dissolved Oxygen (% Sat.)	0.1	1,065	86.6	91.7	37.6	114.2	-----	-----	-----
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	331	7.7	7.7	3.8	11.0	5[1,4]	4	12%
Specific Conductance (umho/cm)	1	1,065	602	605	544	656	-----	-----	-----
pH (S.U.)	0.1	1,065	8.3	8.3	7.3	8.9	7.0[1,4], 9.0[1,3]	0	0%
Turbidity (NTUs)	1	1,063	-----	3	n.d.	62	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	1,065	372	360	243	538	-----	-----	-----
Secchi Depth (in.)	1	25	100	96	36	216	-----	-----	-----
Alkalinity, Total (mg/l)	7	51	158	157	140	180	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	49	2.9	3.0	1.3	4.6	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	44	10	10	n.d.	28	-----	-----	-----
Chloride (mg/l)	1	42	9	10	5	11	100[1,3]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	614	5	4	n.d.	29	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	25	3	2	n.d.	16	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	49	430	420	364	510	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	53	-----	0.02	n.d.	0.13	3.2[1,3,5], 1.4[1,5,6]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	53	0.3	0.3	n.d.	1.3	-----	-----	-----
Nitrogen, Nitrate-Nitrite N, Total (mg/l)	0.02	53	-----	0.06	n.d.	0.20	1.0[1,3], 0.25[7]	0	0%
Nitrogen, Total (mg/l)	0.1	53	0.4	0.4	n.d.	1.3	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	53	-----	n.d.	n.d.	0.05	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	53	0.04	0.03	n.d.	0.37	0.02[7]	32	58%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	53	-----	n.d.	n.d.	0.05	-----	-----	-----
Sulfate (mg/l)	1	49	160	160	121	180	250[1,3]	0	0%
Suspended Solids, Total (mg/l)	4	53	-----	n.d.	n.d.	55	-----	-----	-----
Microcystin, Total (ug/l)	0.2	24	-----	n.d.	n.d.	0.4	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for Class 1 lakes.
- (2) Applies to hypolimnion of Class 1 lakes during periods of thermal stratification.
- (3) Daily maximum criterion (monitoring results directly comparable to criterion).
- (4) Daily minimum criterion (monitoring results directly comparable to criterion).
- (5) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Nutrient guideline for lake or reservoir improvement or management.

(E) The top of the hypolimnion is generally defined as the depth where a temperature drop of at least 0.5°C last occurs over a 1-meter depth increment.

Plate 65. Summary of monthly (May through September) water quality conditions monitored in Lake Sakakawea near Beulah Bay (Site GARLK1412DW) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	26	1819.9	1816.1	1807.4	1842.4	-----	-----	-----
Water Temperature (°C)	0.1	924	14.3	15.3	4.7	23.3	29.4(1,3)	0	0%
Hypolimnion Water Temperature (°C)[E]	0.1	256	11.4	11.8	6.3	16.6	15.0(2,3)	27	11%
Dissolved Oxygen (mg/l)	0.1	924	8.5	8.5	2.8	12.2	5(1,4)	63	7%
Dissolved Oxygen (% Sat.)	0.1	858	85.6	91.2	28.3	116.6	-----	-----	-----
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	256	7.5	7.2	2.8	11.0	5(1,4)	65	32%
Specific Conductance (umho/cm)	1	858	595	598	523	655	-----	-----	-----
pH (S.U.)	0.1	858	8.3	8.3	7.3	9.0	7.0(1,4), 9.0(1,4)	0	0%
Turbidity (NTUs)	1	856	-----	2	n.d.	37	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	858	375	362	212	535	-----	-----	-----
Secchi Depth (in.)	1	24	99	108	37	140	-----	-----	-----
Alkalinity, Total (mg/l)	7	51	156	156	130	180	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	49	3.0	3.0	1.2	5.0	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	40	11	11	n.d.	61	-----	-----	-----
Chloride (mg/l)	1	40	9	10	8	11	100(1,3)	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	504	8	3	n.d.	63	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	23	5	3	n.d.	45	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	51	420	420	350	572	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	51	-----	0.03	n.d.	0.14	3.1(1,3,5), 1.4(1,5,6)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	51	0.4	0.3	n.d.	1.1	-----	-----	-----
Nitrogen, Nitrate-Nitrite N, Total (mg/l)	0.02	51	-----	0.06	n.d.	0.20	1.0(1,3), 0.25(7)	0	0%
Nitrogen, Total (mg/l)	0.1	51	0.4	0.4	n.d.	1.3	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	51	----	n.d.	n.d.	0.27	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	51	0.04	0.02	n.d.	0.33	0.02(7)	28	55%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	51	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	51	159	157	150	180	250(1,3)	0	0%
Suspended Solids, Total (mg/l)	4	51	-----	n.d.	n.d.	11	-----	-----	-----
Microcystin, Total (ug/l)	0.2	21	-----	n.d.	n.d.	0.4	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for Class 1 lakes.
- (2) Applies to hypolimnion of Class 1 lakes during periods of thermal stratification.
- (3) Daily maximum criterion (monitoring results directly comparable to criterion).
- (4) Daily minimum criterion (monitoring results directly comparable to criterion).
- (5) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Nutrient guideline for lake or reservoir improvement or management.

(E) The top of the hypolimnion is generally defined as the depth where a temperature drop of at least 0.5°C last occurs over a 1-meter depth increment.

Plate 66. Summary of monthly (May through September) water quality conditions monitored in Lake Sakakawea near Deepwater Bay (Site GARLK1445DW) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	25	1819.0	1816.0	1807.5	1842.4	-----	-----	-----
Water Temperature (°C)	0.1	677	15.7	16.5	5.7	24.8	29.4[1,3]	0	0%
Hypolimnion Water Temperature (°C)[E]	0.1	151	12.5	12.7	7.4	17.1	15.0[2,3]	29	19%
Dissolved Oxygen (mg/l)	0.1	677	8.1	8.2	1.0	12.4	5[1,4]	58	9%
Dissolved Oxygen (% Sat.)	0.1	629	83.1	88.6	10.0	110.4	-----	-----	-----
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	151	6.6	7.2	1.0	9.8	5[1,4]	37	25%
Specific Conductance (umho/cm)	1	628	557	567	471	672	-----	-----	-----
pH (S.U.)	0.1	603	8.2	8.3	7.1	9.0	7.0[1,4], 9.0[1,4]	0	0%
Turbidity (NTUs)	1	622	8	5	n.d.	68	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	629	350	338	139	492	-----	-----	-----
Secchi Depth (in.)	1	22	79	72	24	192	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	144	143	89	180	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	46	3.1	3.1	n.d.	5.2	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	38	12	11	n.d.	58	-----	-----	-----
Chloride (mg/l)	1	38	9	9	6	12	100[1,3]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	361	10	4	n.d.	75	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	22	5	3	n.d.	20	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	48	399	385	280	536	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	48	-----	0.03	n.d.	0.09	3.2[1,3,5], 1.3[1,5,6]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	48	0.4	0.3	n.d.	1.5	-----	-----	-----
Nitrogen, Nitrate-Nitrite N, Total (mg/l)	0.02	48	-----	0.08	n.d.	0.30	1.0[1,3], 0.25[7]	0, 1	0%, 2%
Nitrogen, Total (mg/l)	0.1	48	0.5	0.4	n.d.	1.6	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	48	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	48	0.03	0.03	n.d.	0.12	0.02[7]	30	63%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	48	-----	n.d.	n.d.	0.07	-----	-----	-----
Sulfate (mg/l)	1	48	149	148	118	190	250[1,3]	0	0%
Suspended Solids, Total (mg/l)	4	48	4	0	0	16	-----	-----	-----
Microcystin, Total (ug/l)	0.2	21	-----	n.d.	n.d.	0.2	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for Class 1 lakes.
- (2) Applies to hypolimnion of Class 1 lakes during periods of thermal stratification.
- (3) Daily maximum criterion (monitoring results directly comparable to criterion).
- (4) Daily minimum criterion (monitoring results directly comparable to criterion).
- (5) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Nutrient guideline for lake or reservoir improvement or management.

(E) The top of the hypolimnion is generally defined as the depth where a temperature drop of at least 0.5°C last occurs over a 1-meter depth increment.

Plate 67. Summary of monthly (May through September) water quality conditions monitored in Lake Sakakawea near New Town (Site GARLK1481DW) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria***	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	24	1820.5	1816.6	1807.5	1842.4	-----	-----	-----
Water Temperature (°C)	0.1	388	17.8	18.4	8.1	26.4	29.4[1,3]	0	0%
Hypolimnion Water Temperature (°C)[E]	0.1	23	13.9	13.3	10.9	19.1	15.0[2,3]	7	30%
Dissolved Oxygen (mg/l)	0.1	388	8.2	8.4	3.8	11.3	5[1,4]	16	4%
Dissolved Oxygen (% Sat.)	0.1	378	89.1	93.0	36.7	114.2	-----	-----	-----
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	23	4.9	4.7	3.8	6.7	5[1,4]	15	65%
Specific Conductance (umho/cm)	1	377	499	481	339	723	-----	-----	-----
pH (S.U.)	0.1	378	8.3	8.3	7.3	8.9	7.0[1,4], 9.0[1,4]	0	0%
Turbidity (NTUs)	1	375	33	13	n.d.	360	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	378	333	326	250	455	-----	-----	-----
Secchi Depth (in.)	1	24	36	27	8	116	-----	-----	-----
Alkalinity, Total (mg/l)	7	28	133	128	94	171	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	27	3.0	2.9	1.1	5.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	20	6	6	n.d.	21	-----	-----	-----
Chloride (mg/l)	1	20	8	8	4	13	100[1,3]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	240	12	10	n.d.	47	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	23	10	8	n.d.	40	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	28	359	359	234	522	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	28	-----	0.03	n.d.	0.14	3.1[1,3,5], 1.1[1,5,6]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	28	0.5	0.4	0.1	1.7	-----	-----	-----
Nitrogen, Nitrate-Nitrite N, Total (mg/l)	0.02	28	-----	0.03	n.d	0.44	1.0[1,3], 0.25[7]	3	11%
Nitrogen, Total (mg/l)	0.1	28	0.6	0.4	.2	1.8	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	28	-----	0.02	n.d.	0.06	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	28	0.05	0.05	n.d.	0.13	0.02[7]	21	75%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	28	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	28	130	130	74	193	250[1,3]	0	0%
Suspended Solids, Total (mg/l)	4	28	-----	5	n.d.	60	-----	-----	-----
Microcystin, Total (ug/l)	0.2	22	-----	n.d.	n.d.	0.5	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for Class 1 lakes.
- (2) Applies to hypolimnion of Class 1 lakes during periods of thermal stratification.
- (3) Daily maximum criterion (monitoring results directly comparable to criterion).
- (4) Daily minimum criterion (monitoring results directly comparable to criterion).
- (5) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Nutrient guideline for lake or reservoir improvement or management.

(E) The top of the hypolimnion is generally defined as the depth where a temperature drop of at least 0.5°C last occurs over a 1-meter depth increment.

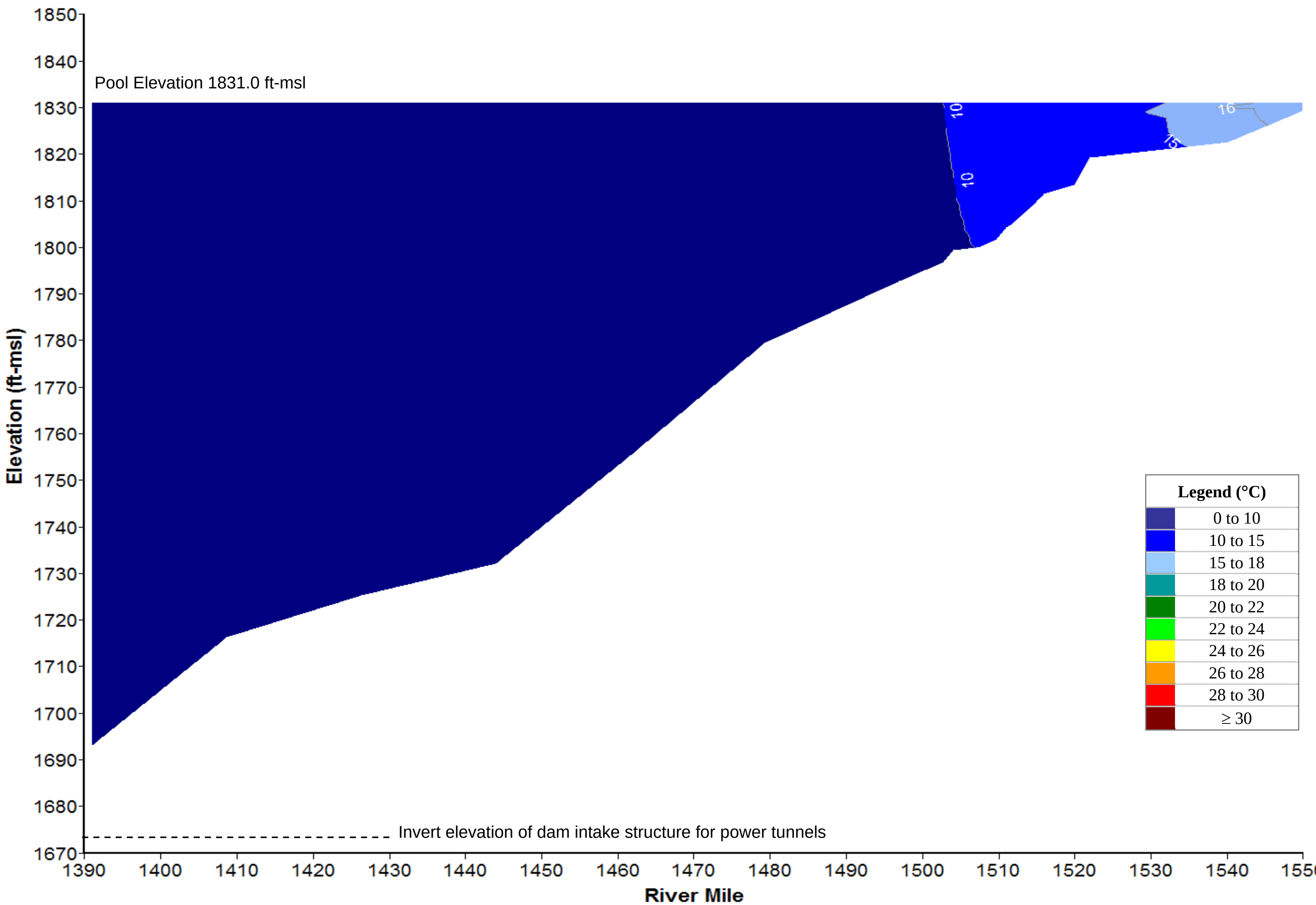


Plate 68. Longitudinal water temperature (°C) contour plot of Lake Sakakawea based on depth-profile water temperatures measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on May 19, 2009.

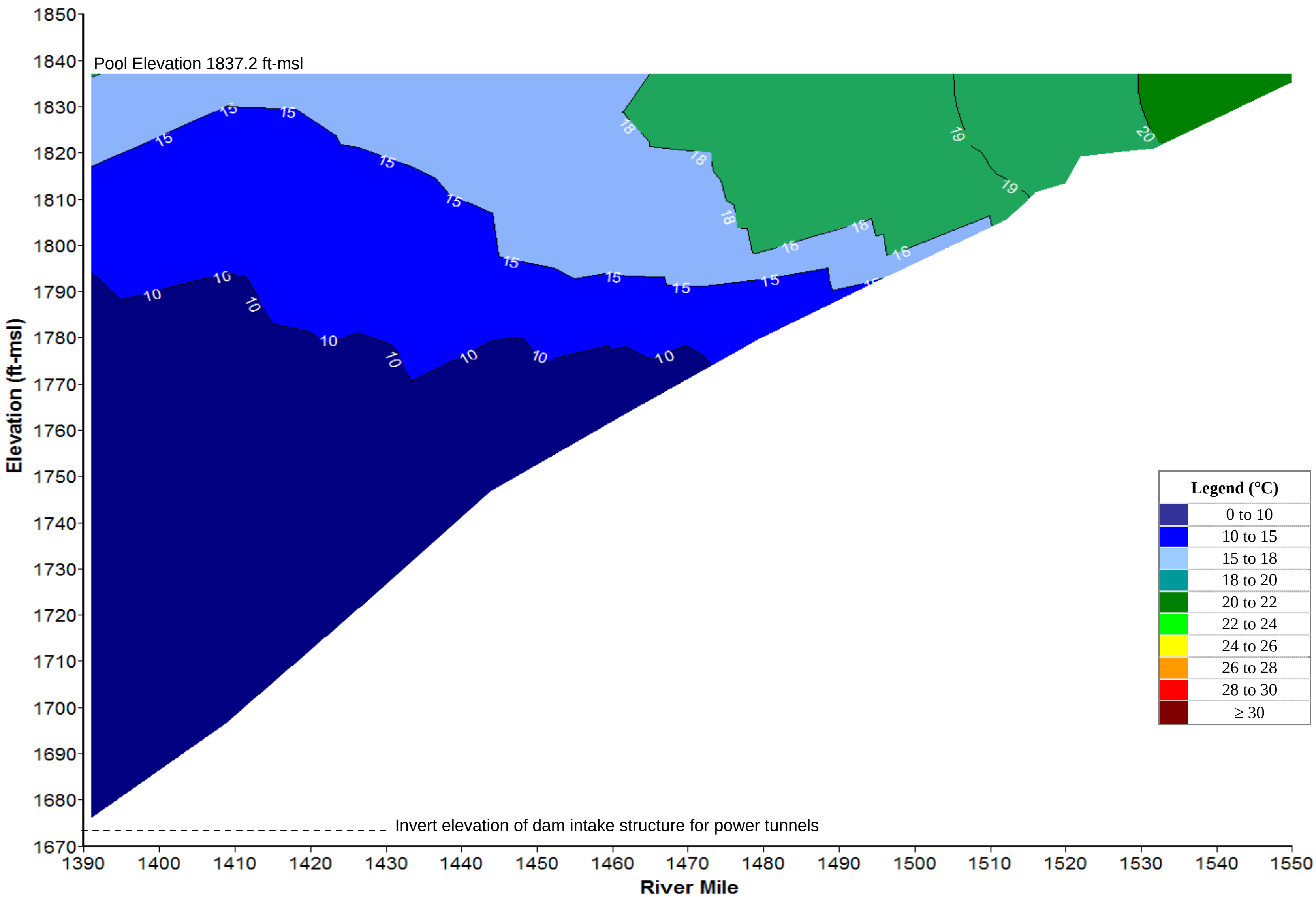


Plate 69. Longitudinal water temperature (°C) contour plot of Lake Sakakawea based on depth-profile water temperatures measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on June 23, 2009.

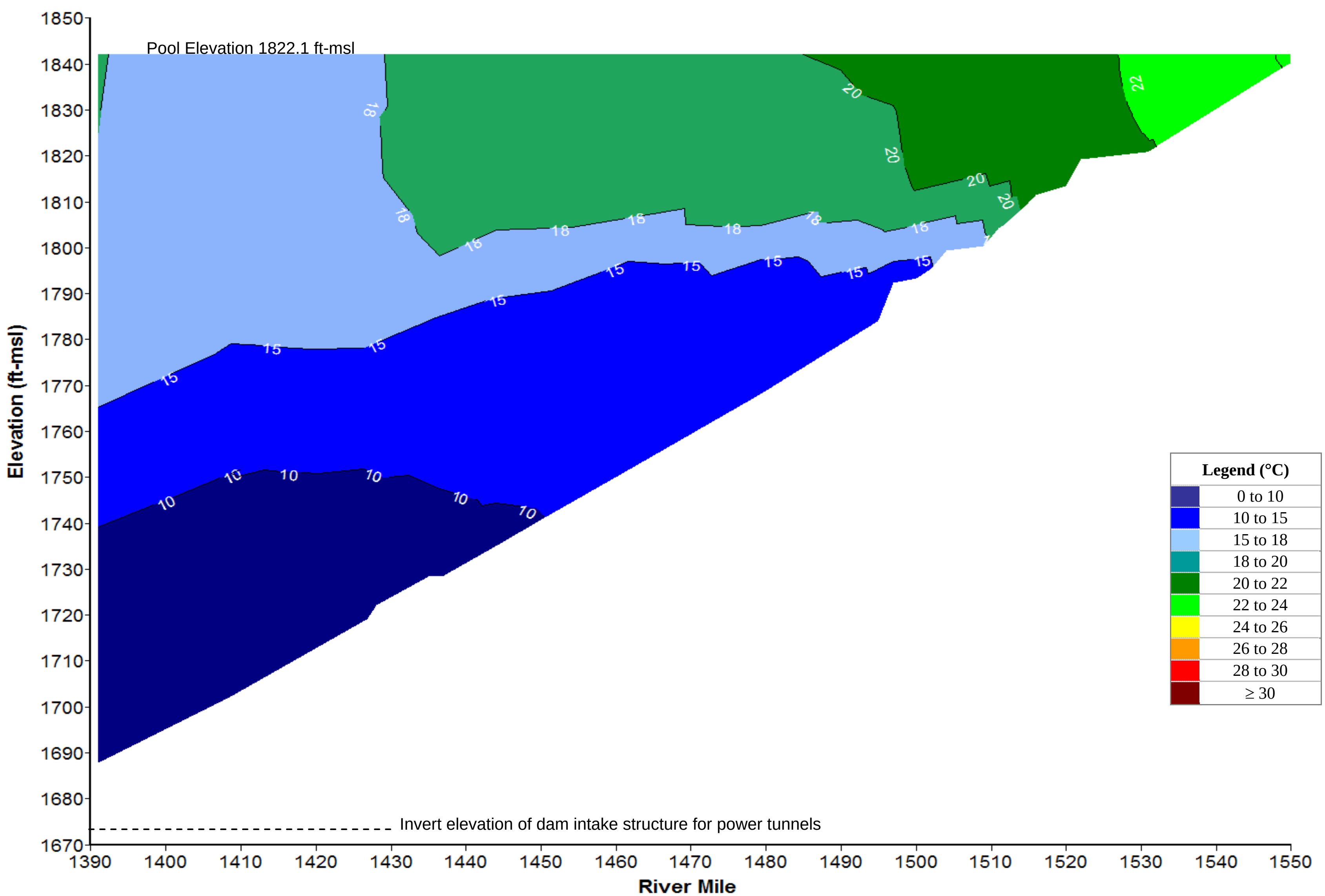


Plate 70. Longitudinal water temperature (°C) contour plot of Lake Sakakawea based on depth-profile water temperatures measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on July 21, 2009.

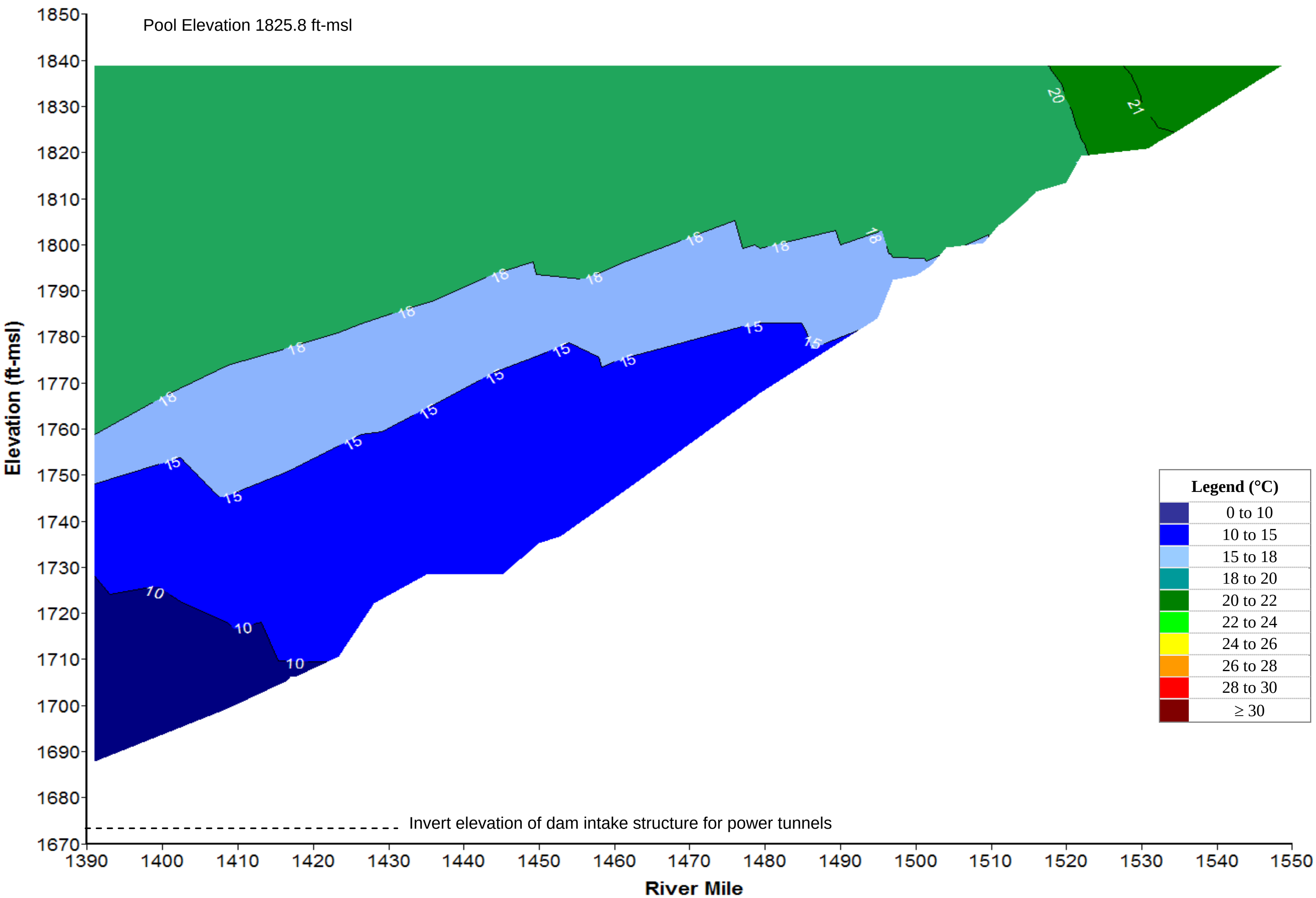


Plate 71. Longitudinal water temperature (°C) contour plot of Lake Sakakawea based on depth-profile water temperatures measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on August 25, 2009.

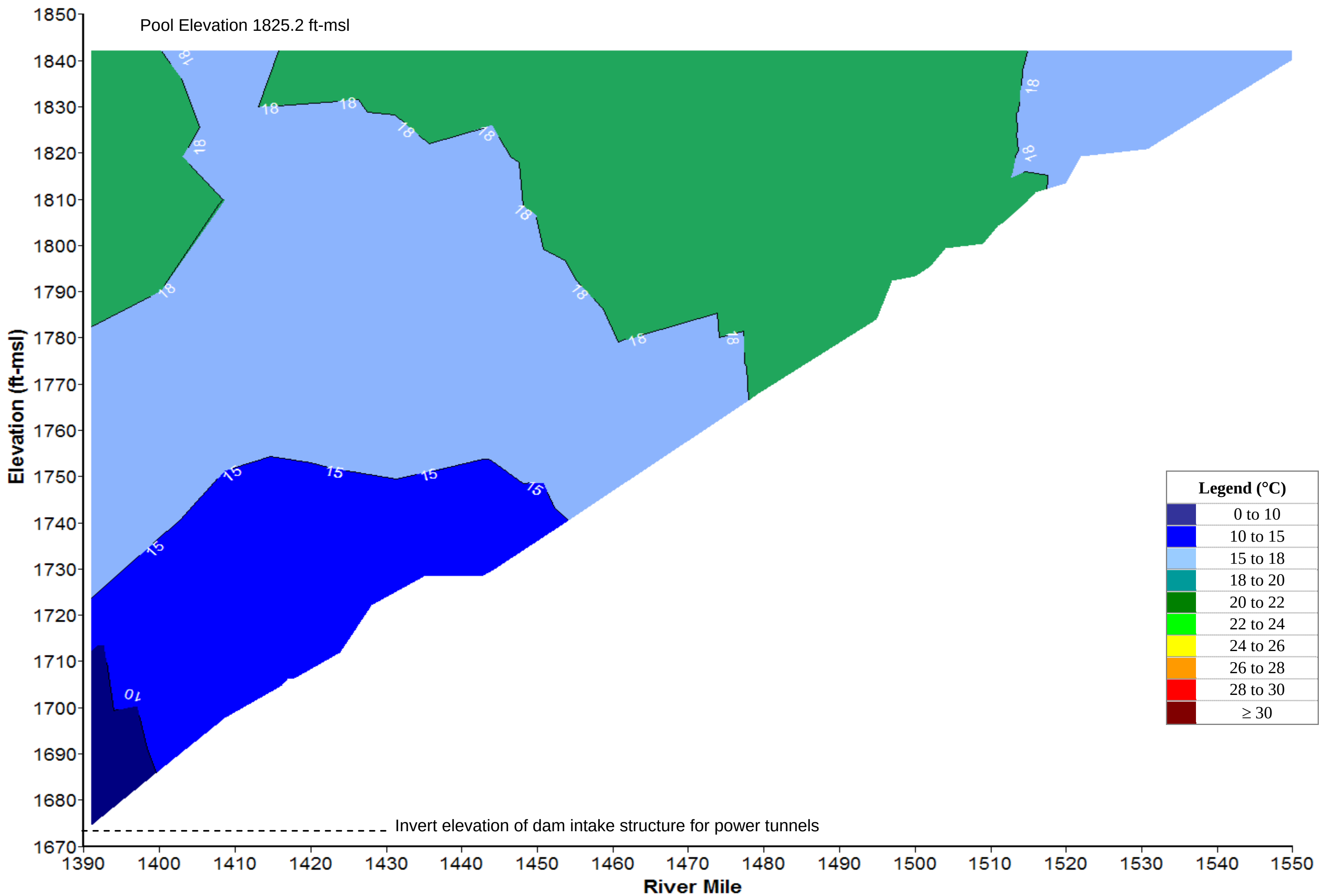


Plate 72. Longitudinal water temperature (°C) contour plot of Lake Sakakawea based on depth-profile water temperatures measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on September 22, 2009.

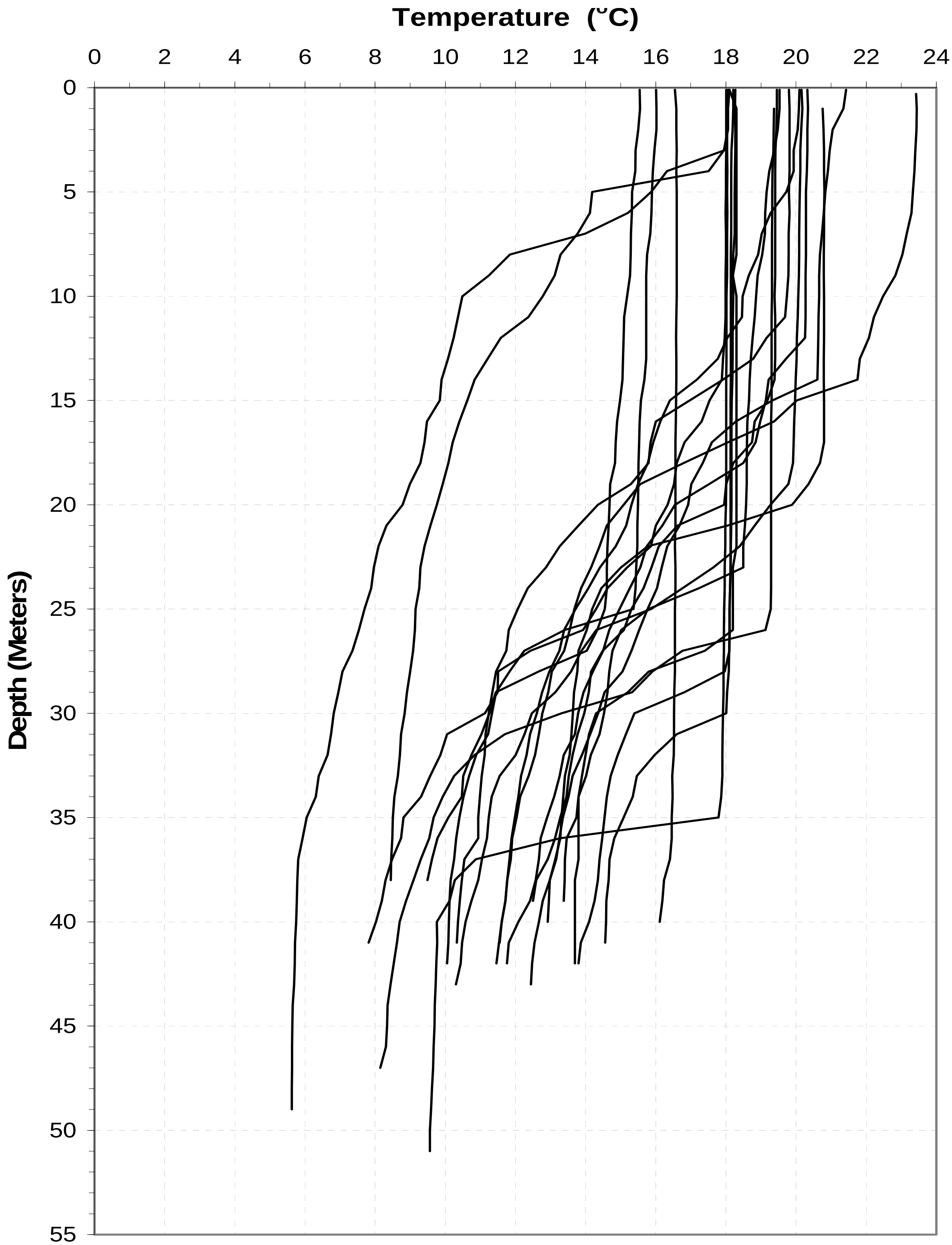


Plate 73. Temperature depth profiles for Lake Sakakawea generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., GARLK1390A) during the summer months over the 5-year period of 2005 to 2009.

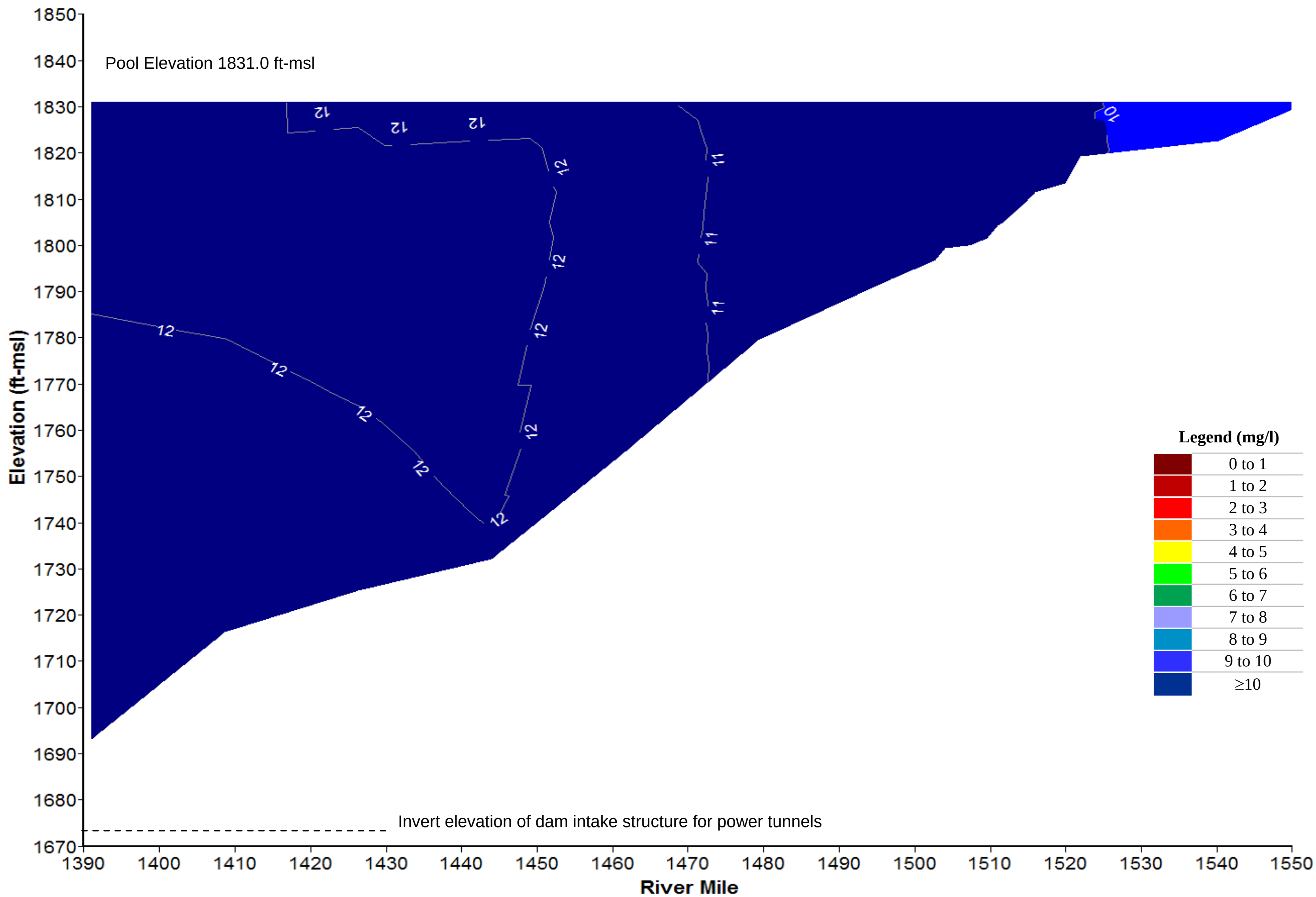


Plate 74. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sakakawea based on depth-profile dissolved oxygen concentrations measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on May 19, 2009.

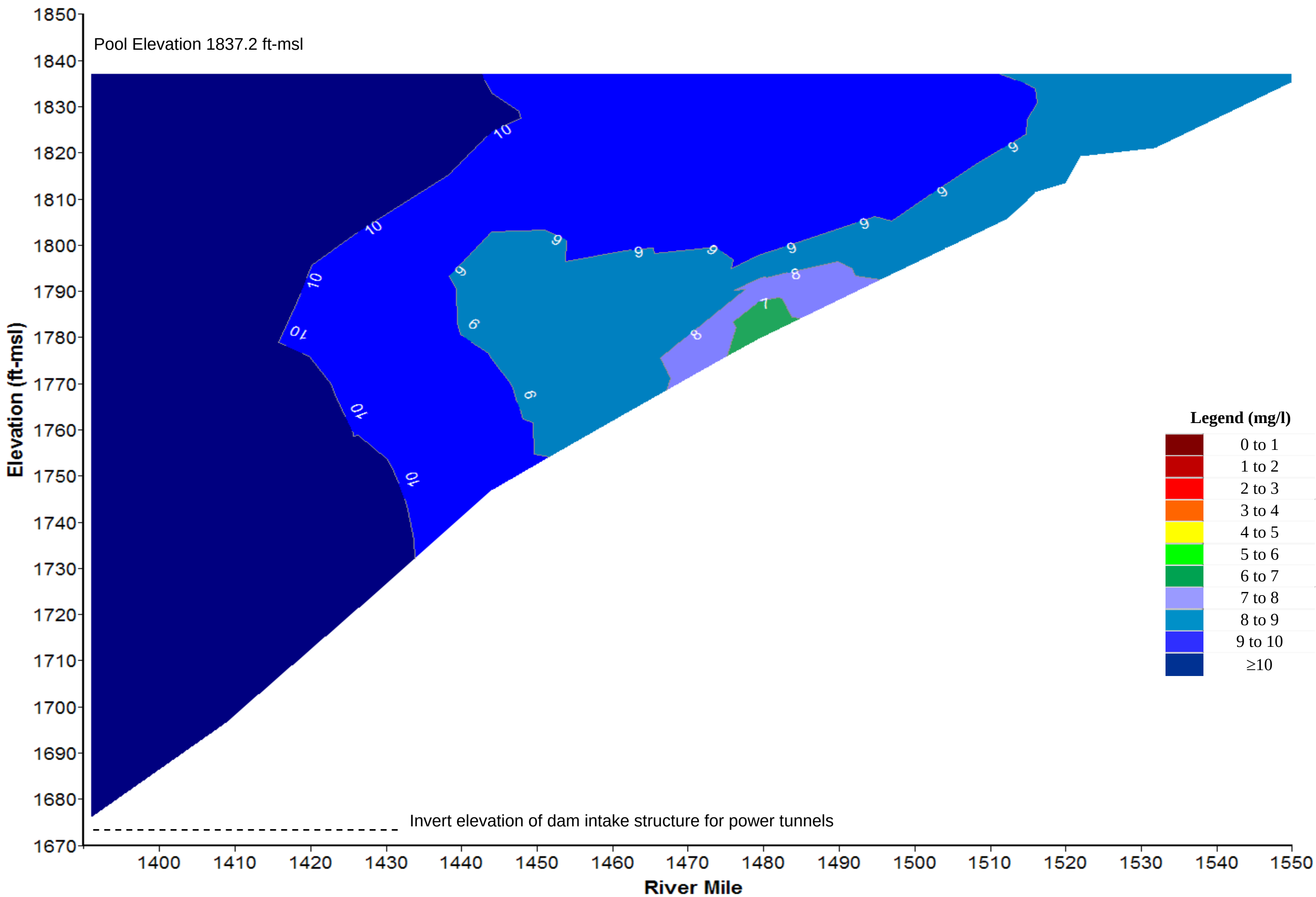


Plate 75. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sakakawea based on depth-profile dissolved oxygen concentrations s measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on June 23, 2009.

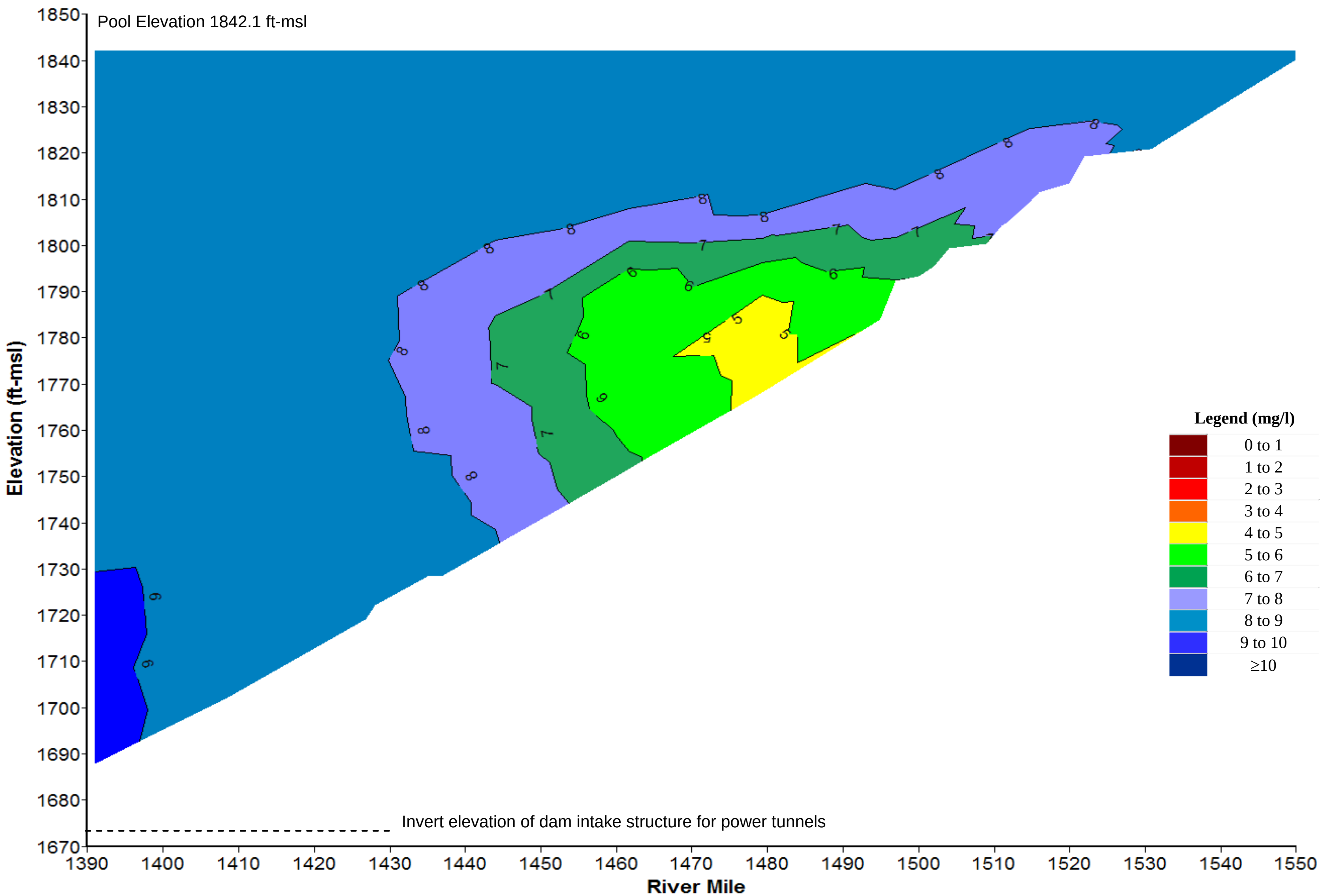


Plate 76. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sakakawea based on depth-profile dissolved oxygen concentrations measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on July 21, 2009.

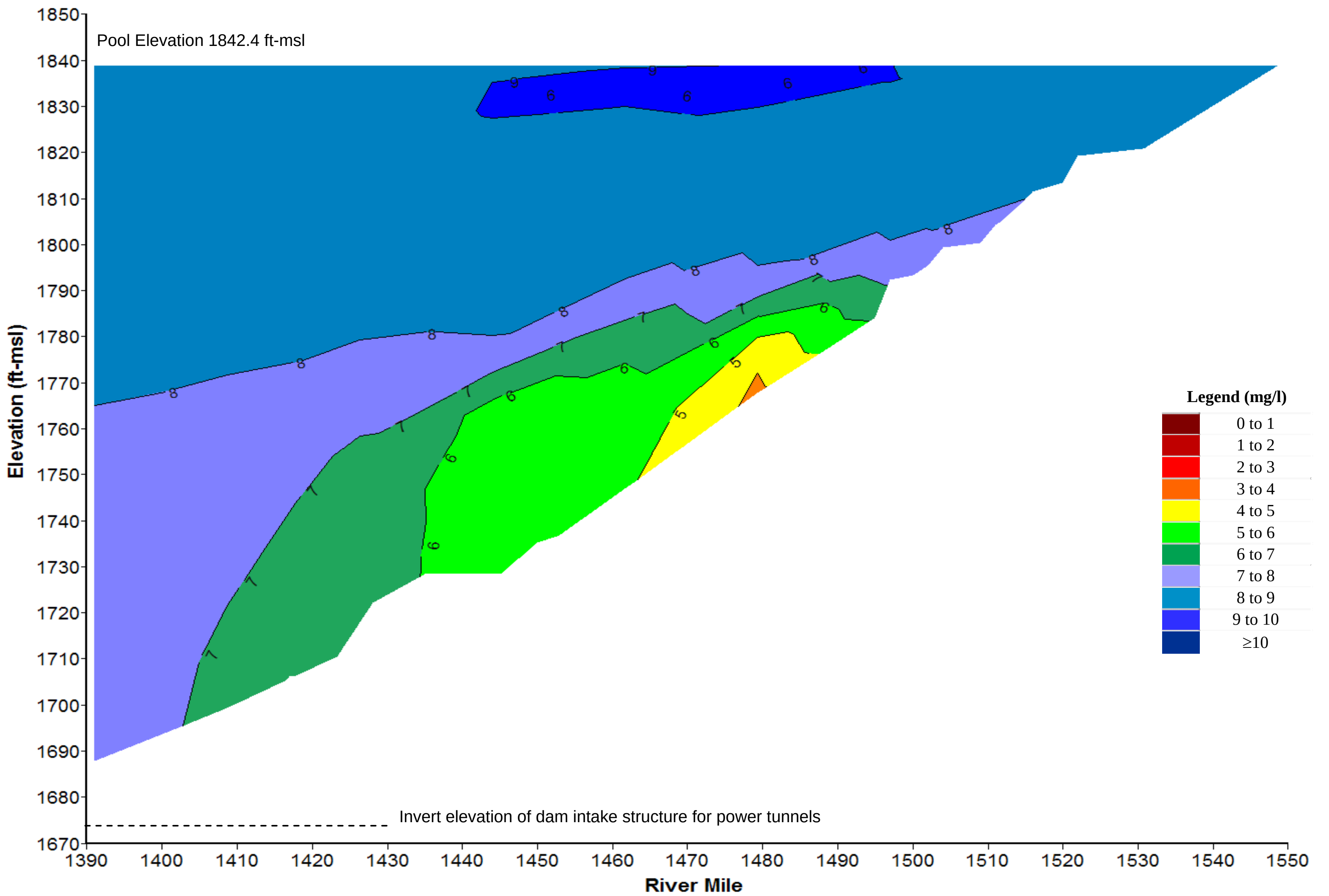


Plate 77. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sakakawea based on depth-profile dissolved oxygen concentrations measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on August 25, 2009.

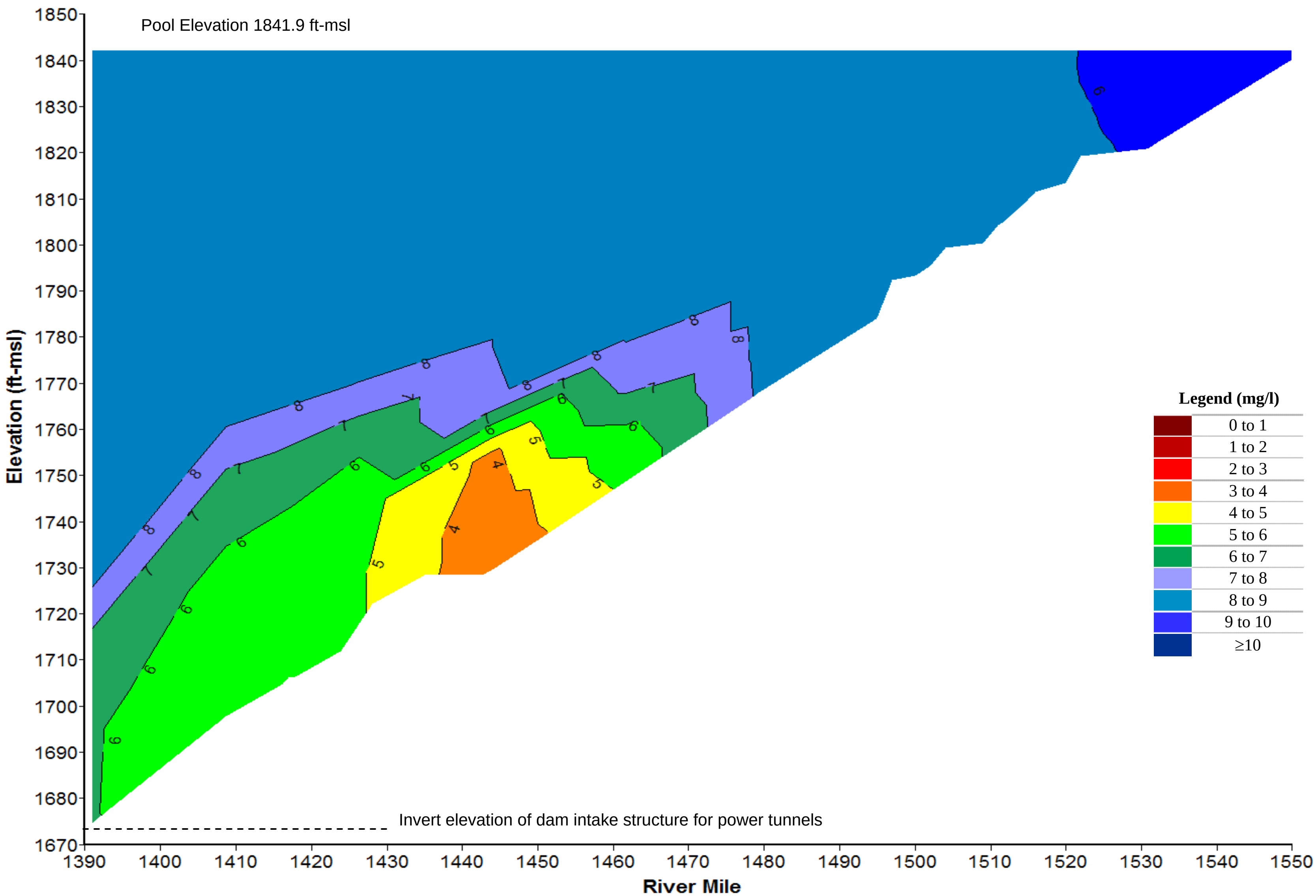


Plate 78. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sakakawea based on depth-profile dissolved oxygen concentrations measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on September 22, 2009.

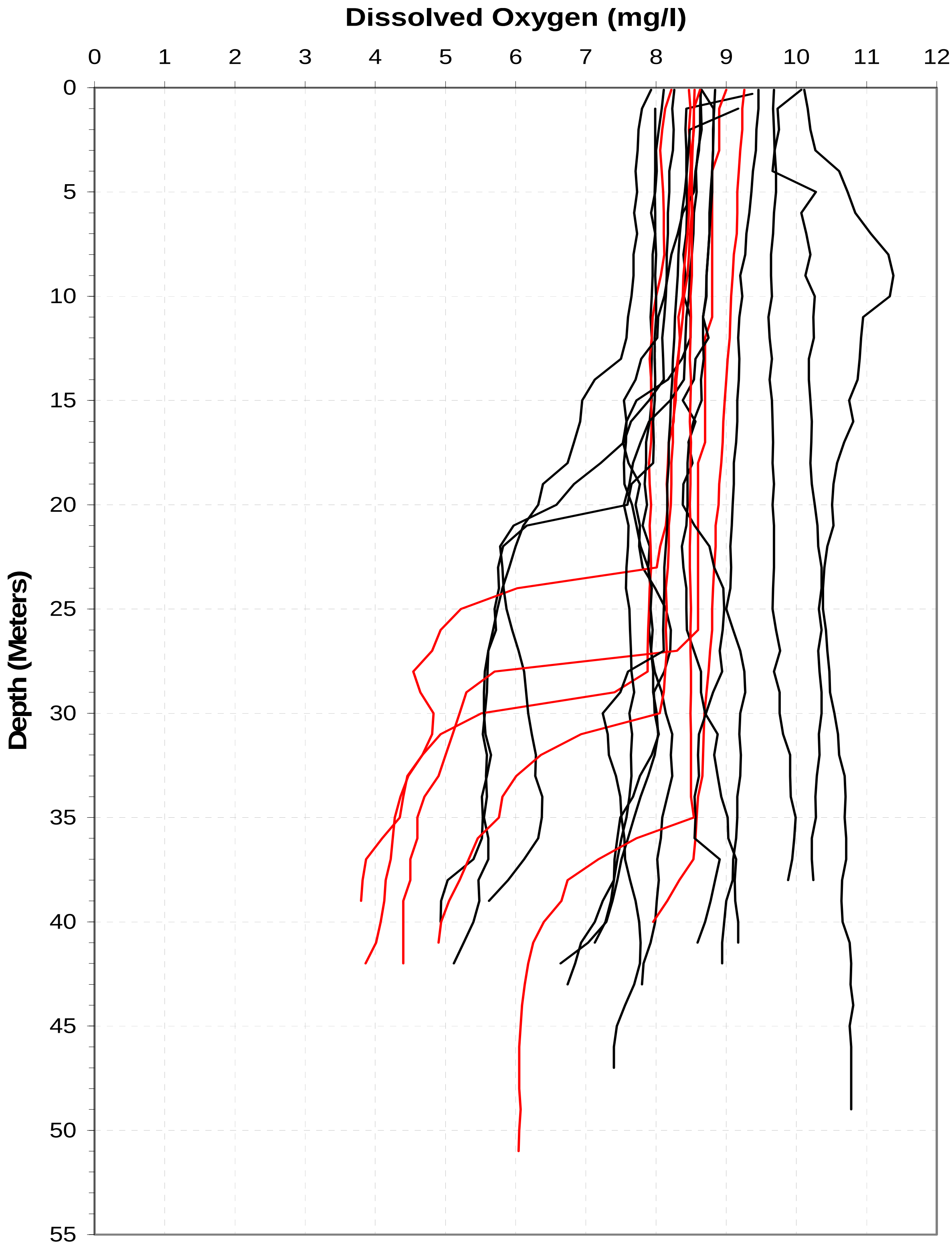


Plate 79. Dissolved oxygen depth profiles for Lake Sakakawea generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., GARLK1390A) during the summer over the 5-year period of 2005 through 2009.
(Note: Red profile plots were measured in the month of September.)

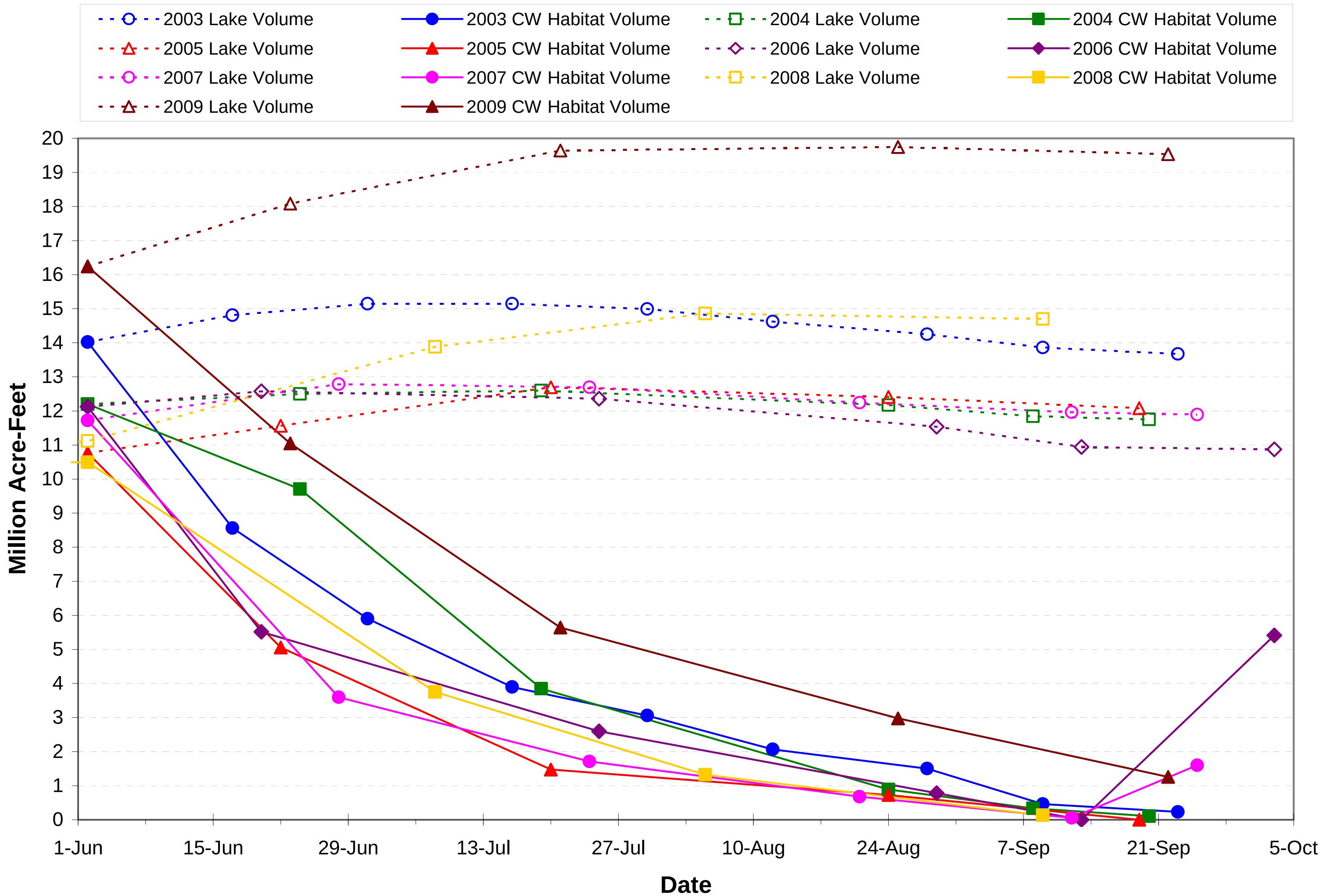


Plate 80. Estimated volume of coldwater fishery habitat in Lake Sakakawea during 2003, 2004, 2005, 2006, 2007, 2008, and 2009.

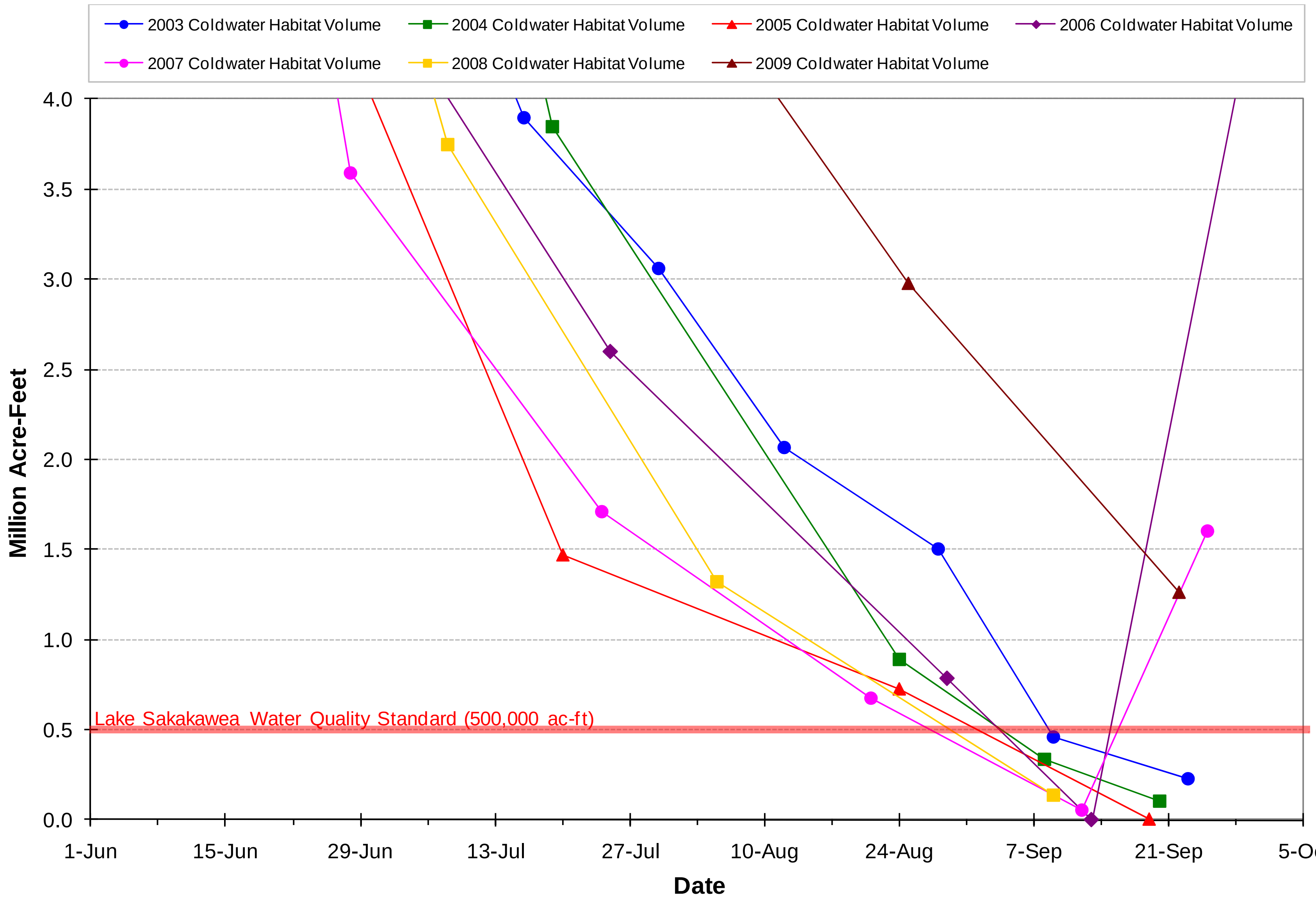


Plate 81. Estimated volume of coldwater fishery habitat in Lake Sakakawea during 2003, 2004, 2005, 2006, 2007, 2008, and 2009. Y-axis scaled to better discern estimated volumes near 500,000 ac-ft water quality standard defined by North Dakota for Lake Sakakawea.

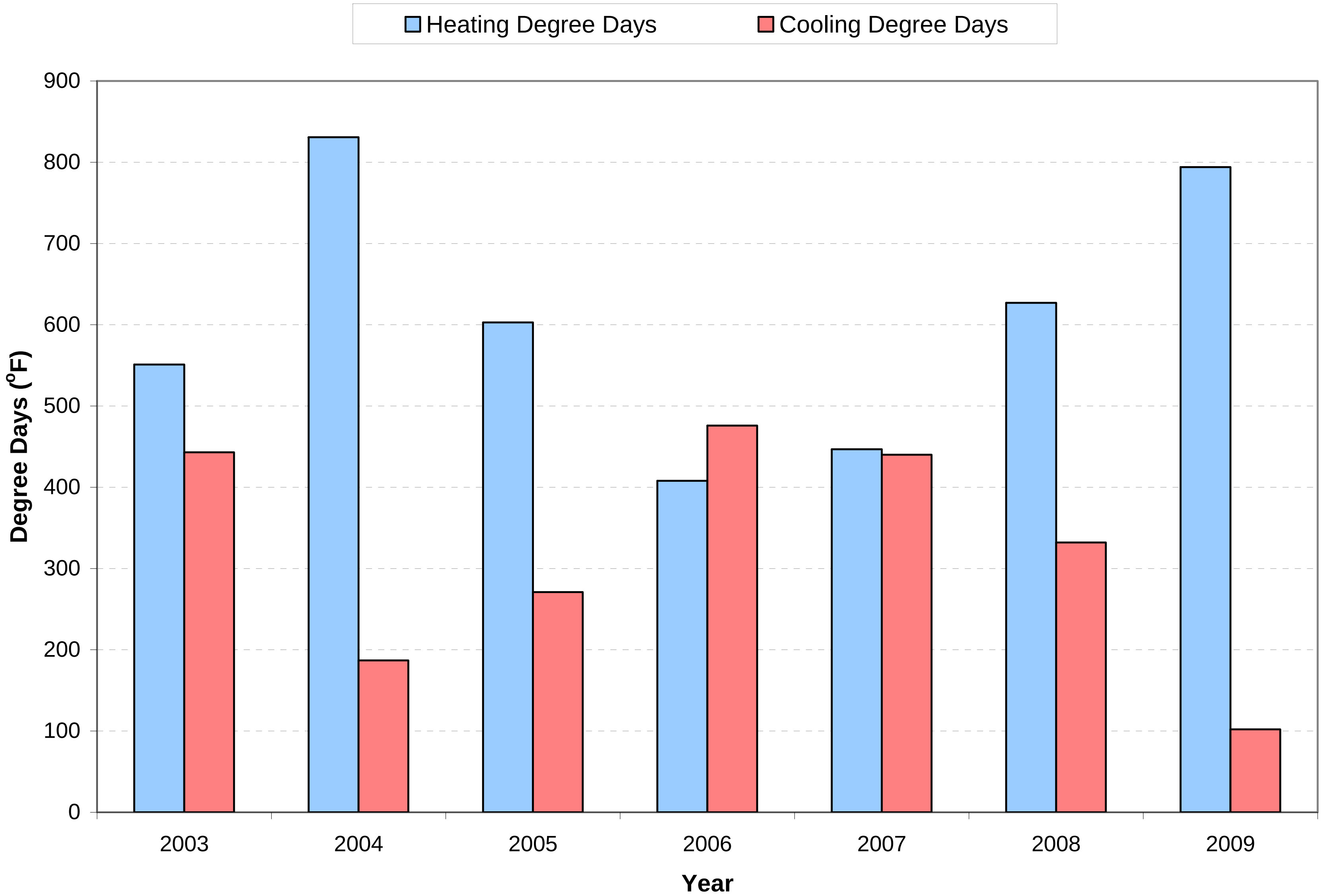


Plate 82. Heating and cooling degree days recorded at Garrison, North Dakota during the 4-month period May through August during 2003, 2004, 2005, 2006, 2007, 2008, and 2009. *(Note: The number in parentheses is the difference in heating and cooling degree days.)*

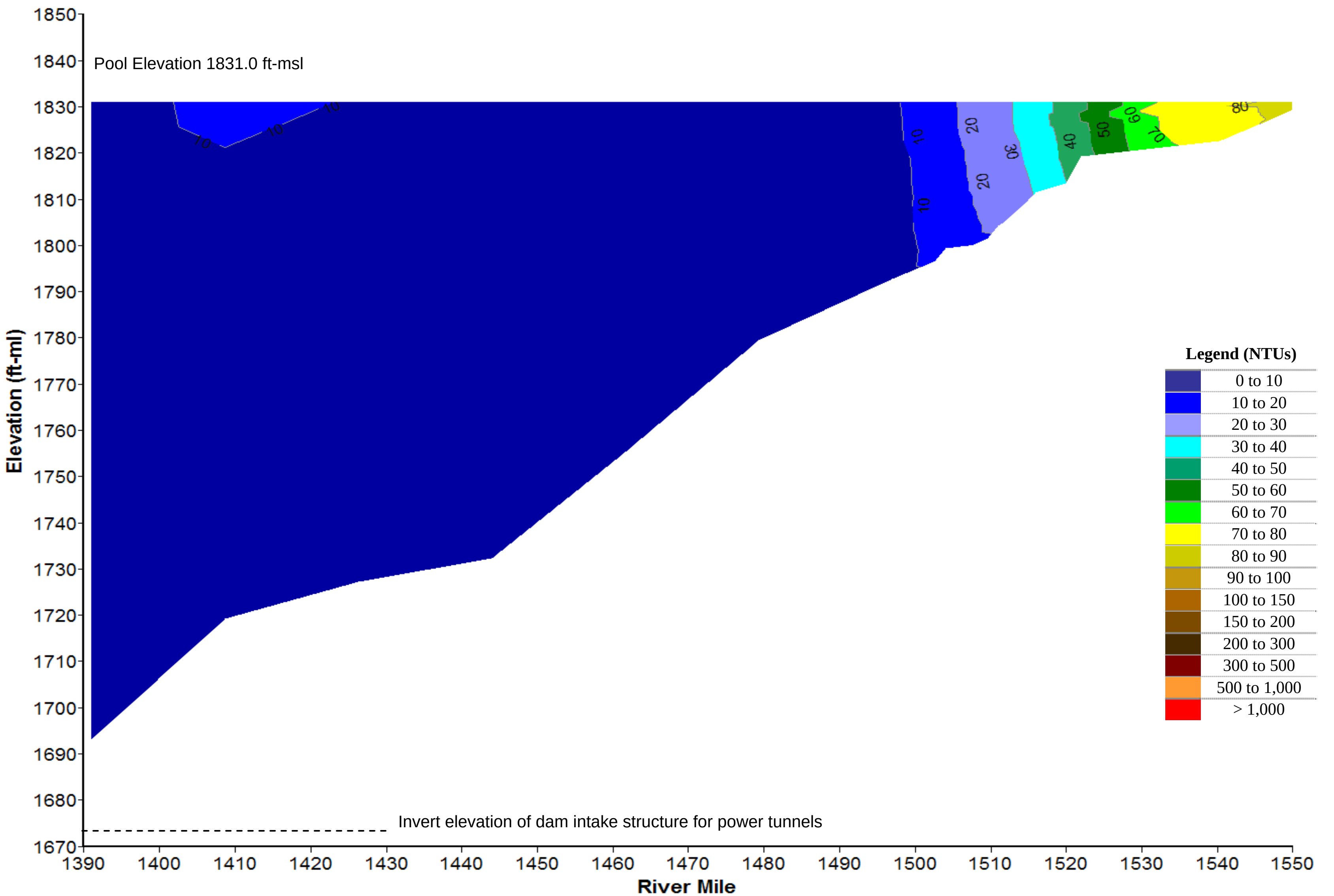


Plate 83. Longitudinal turbidity (NTU) contour plot of Lake Sakakawea based on depth-profile turbidity levels monitored at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on May 19, 2009**.**

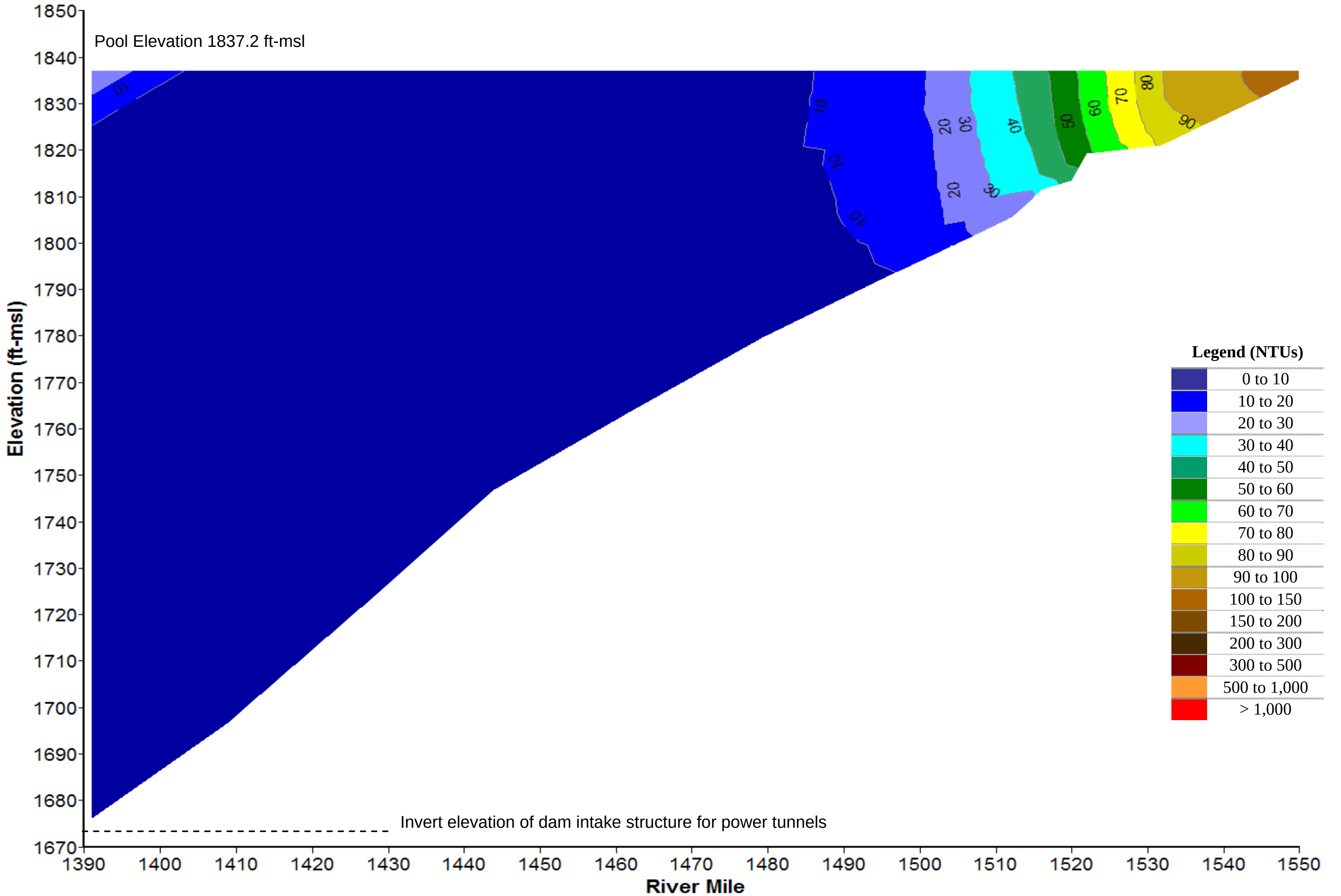


Plate 84. Longitudinal turbidity (NTU) contour plot of Lake Sakakawea based on depth-profile turbidity levels monitored at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on June 23, 2009**.**

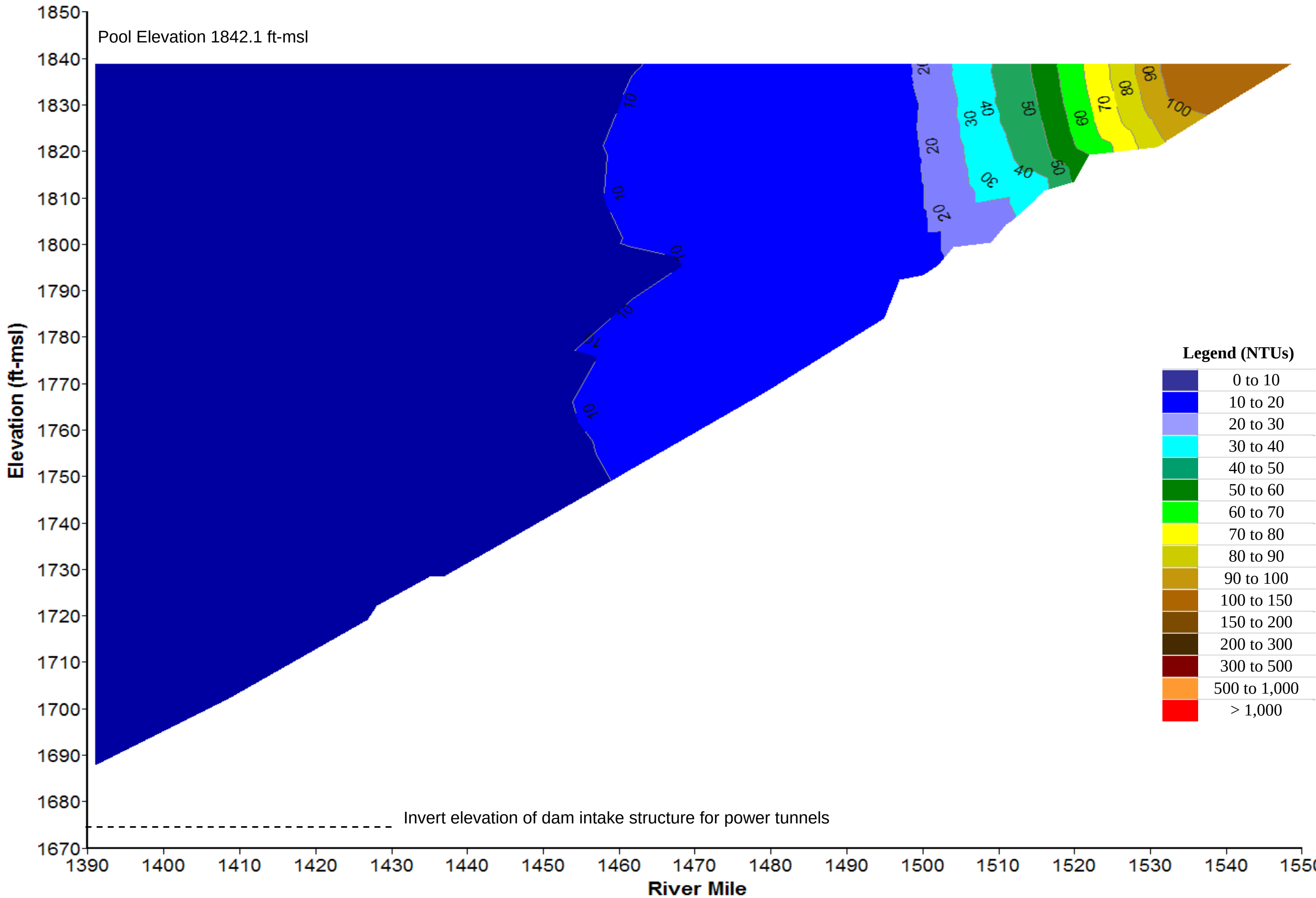


Plate 85. Longitudinal turbidity (NTU) contour plot of Lake Sakakawea based on depth-profile turbidity levels monitored at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on July 21, 2009.

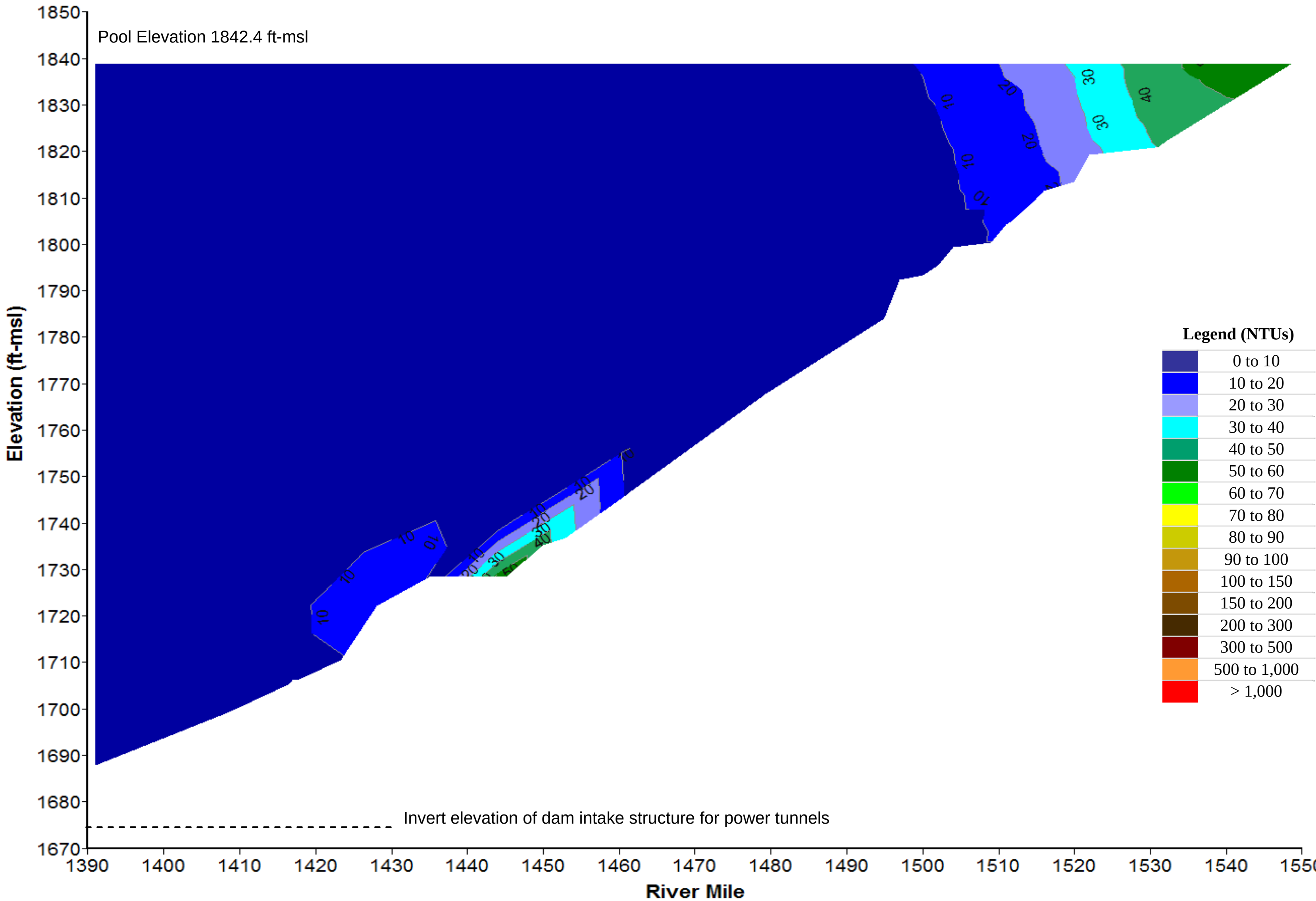


Plate 86. Longitudinal turbidity (NTU) contour plot of Lake Sakakawea based on depth-profile turbidity levels monitored at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on August 25, 2009**.**

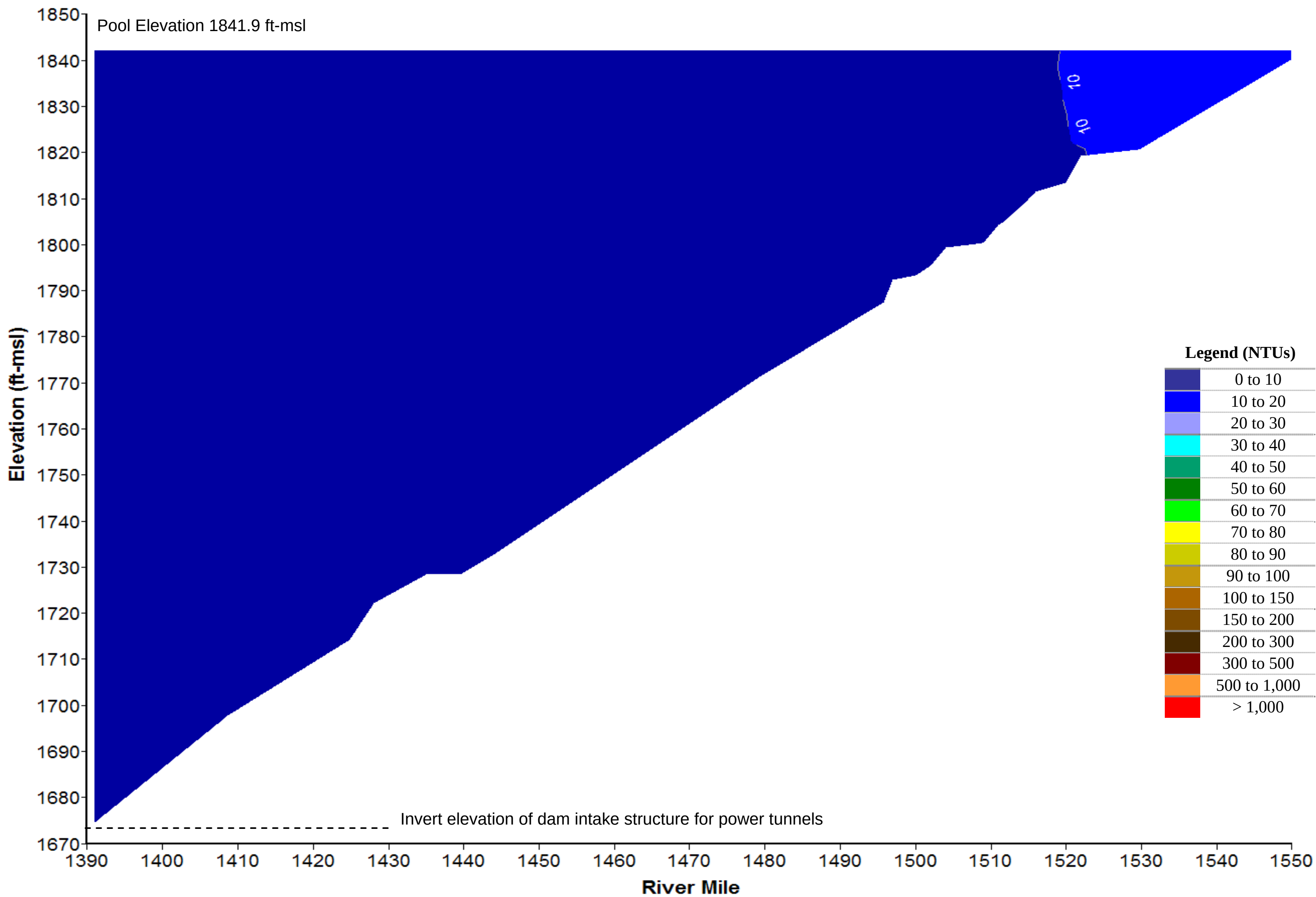


Plate 87. Longitudinal turbidity (NTU) contour plot of Lake Sakakawea based on depth-profile turbidity levels monitored at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on September 22, 2009**.**

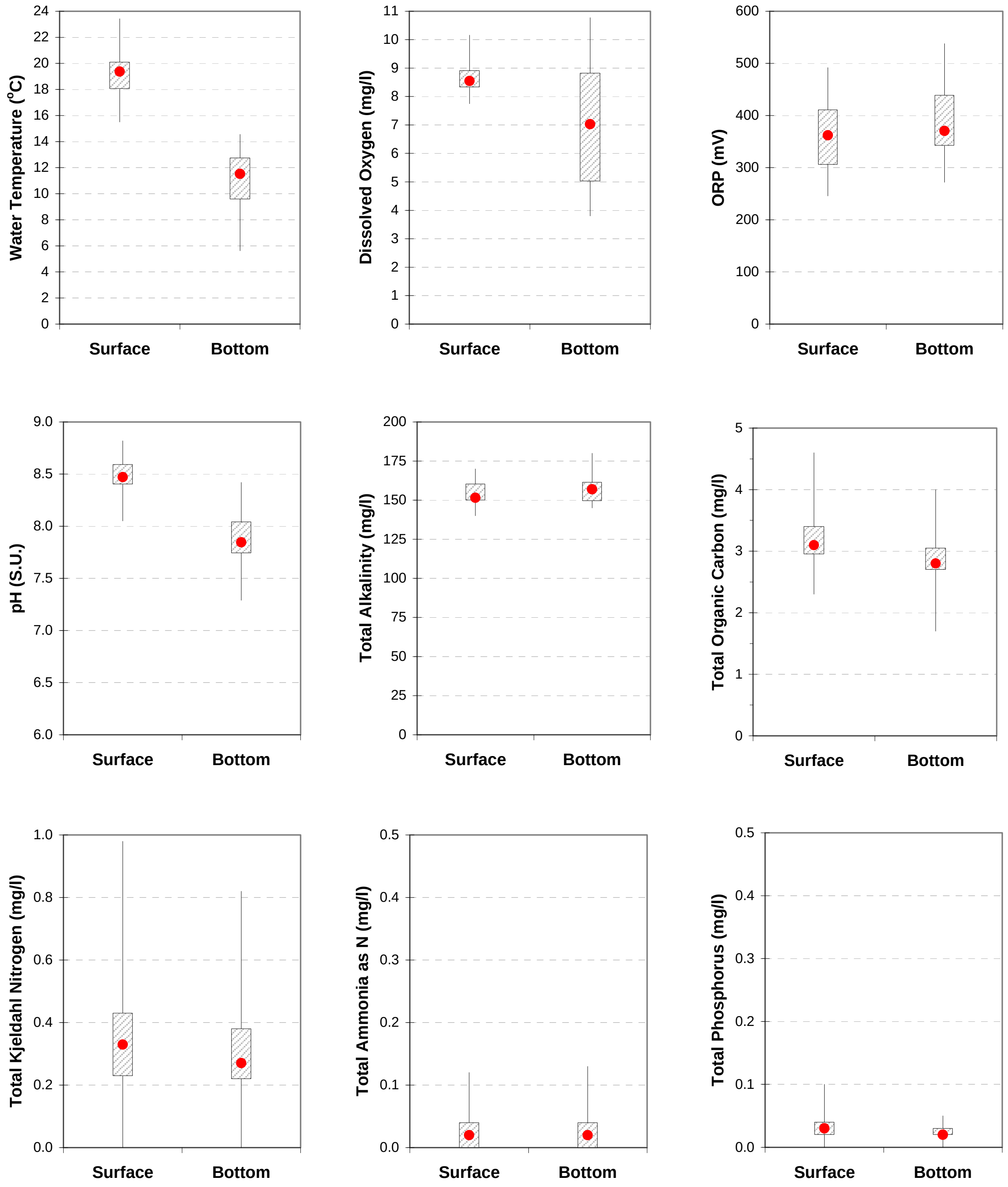


Plate 88. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Lake Sakakawea at site GARLK1390A during the summer months of the 5-year period 2005 through 2009.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 89. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Sakakawea at site GARLK1390A during the 5-year period 2005 through 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
May 2005	1,366,154,039	8	0.99	4	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----	1.41
Jun 2005	6,163,686	1	0.88	0	-----	0	-----	0	-----	2	0.12	0	-----	0	-----	0.46
Jul 2005	56,944,302	7	0.57	2	0.19	0	-----	2	0.24	1	<0.01	0	-----	0	-----	1.82
Aug 2005	103,732,272	4	0.42	4	0.11	0	-----	1	0.29	2	<0.01	2	0.18	0	-----	1.93
Sep 2005	104,058,345	7	0.48	3	0.23	0	-----	2	0.29	2	<0.01	0	-----	0	-----	1.87
May 2006	4,548,278	2	0.36	5	0.45	0	-----	1	0.16	1	0.02	0	-----	0	-----	1.88
Jun 2006	207,770,143	3	0.99	2	<0.01	0	<0.01	1	0.01	1	<0.01	0	-----	0	-----	0.58
Jul 2006	95,265,098	4	0.95	3	0.01	0	-----	1	0.03	0	-----	0	-----	1	<0.01	0.41
Aug 2006	61,320,561	5	0.54	3	0.14	1	0.01	1	0.11	1	0.01	1	0.16	1	0.03	1.86
Oct 2006	149,224,845	6	0.82	2	0.09	0	-----	1	0.09	0	-----	0	-----	1	<0.01	1.23
May 2007	233,328,700	7	0.82	2	0.05	1	0.05	1	0.03	0	-----	1	0.05	0	-----	1.28
June 2007	460,925,551	7	0.85	2	0.08	2	0.03	1	0.04	0	-----	1	<0.01	0	-----	0.81
July 2007	61,884,196	9	0.54	9	0.21	0	-----	1	0.21	0	-----	1	0.04	0	-----	2.29
Aug 2007	95,896,430	5	0.40	8	0.05	1	0.17	1	0.06	2	<0.01	2	0.32	0	-----	1.84
Sep 2007	115,978,027	9	0.34	6	0.18	0	-----	1	0.07	3	0.01	2	0.42	0	-----	2.07
May 2008	1,157,155,594	6	1.00	1	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----	0.75
Jun 2008	1,679,144,925	10	1.00	0	-----	1	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	1.31
Jul 2008	348,335	5	0.99	2	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----	1.26
Aug 2008	12,401,108	2	0.07	1	0.14	1	0.33	1	0.23	2	0.01	1	0.22	0	-----	1.54
Sep 2008	196,440,443	5	0.94	4	0.01	0	-----	1	0.05	1	<0.01	0	-----	0	-----	1.19
May 2009	412,285,799	5	0.13	2	0.69	1	<0.01	2	0.17	1	<0.01	1	0.01	0	-----	1.12
Jun 2009	287,393,286	6	0.77	2	0.04	2	0.12	2	0.06	1	<0.01	0	-----	1	<0.01	1.64
Jul 2009	145,503,652	5	0.64	5	0.15	1	0.03	1	0.12	1	0.05	1	0.01	0	-----	1.55
Aug 2009**	1,782,235,211	7	0.87	4	0.01	0	-----	1	0.03	4	0.06	1	0.03	1	<0.01	1.56
Sep 2009	6,487,750,828	7	0.06	4	0.01	0	-----	2	0.03	4	0.90	0	-----	0	-----	0.51
Mean*	**611,354,146**	**5.7**	**0.66**	**3.2**	**0.12**	**0.6**	**0.06**	**1.2**	**0.10**	**1.2**	**0.07**	**0.6**	**0.13**	**0.2**	**<0.01**	**1.37**

* Mean percent composition represents the mean when taxa of that division are present.

** The species *Ophiocytium cochleare* in the Division Xanthophyta was identified for the first time at Lake Sakakawea. The percent composition was <0.01.

Plate 90. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Sakakawea at site GARLK1412DW during the 5-year period 2005 through 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jul 2005	116,539,612	5	0.09	4	0.07	1	0.20	2	0.31	2	<0.01	1	0.32	0	-----	1.89
Aug 2005	252,450,665	4	0.82	2	0.09	0	-----	2	0.07	3	0.02	0	-----	0	-----	1.39
Sep 2005	76,108,173	8	0.38	5	0.11	0	-----	2	0.36	7	0.14	1	<0.01	0	-----	2.24
May 2006	217,281,884	6	1.00	1	<0.01	0	-----	1	<0.01	1	<0.01	0	-----	0	-----	1.13
Jun 2006	93,779,718	3	0.76	7	0.05	0	-----	1	0.14	0	-----	1	<0.01	1	0.05	1.13
Jul 2006	397,827,012	6	0.87	4	0.02	2	0.01	1	0.07	2	<0.01	2	0.03	0	-----	0.77
Aug 2006	123,147,584	2	0.61	6	0.07	0	-----	1	0.14	1	0.01	2	<0.01	1	0.17	1.66
Oct 2006	577,387,603	8	0.88	1	<0.01	0	-----	1	0.01	2	0.06	3	0.04	0	-----	1.22
May 2007	111,867,224	11	0.69	3	0.17	1	0.06	1	0.08	0	-----	0	-----	0	-----	1.44
June 2007	119,135,131	8	0.65	5	0.13	2	0.15	1	0.07	0	-----	0	-----	0	-----	1.64
July 2007	204,517,663	6	0.72	6	0.07	1	0.03	1	0.09	2	0.01	1	0.07	0	-----	1.67
Aug 2007	157,266,490	6	0.26	7	0.17	2	0.01	1	0.10	3	0.01	1	0.46	0	-----	1.61
Sep 2007	229,575,999	7	0.54	5	0.06	1	<0.01	2	0.03	5	0.02	1	0.35	0	-----	1.66
May 2008	757,782,264	6	1.00	1	<0.01	1	<0.01	1	<0.01	1	<0.01	1	<0.01	0	-----	0.34
Jun 2008	738,288,567	9	0.99	0	-----	2	<0.01	0	<0.01	0	<0.01	0	-----	0	-----	1.06
Jul 2008	111,538	3	0.19	6	0.16	2	0.03	1	0.56	0	-----	2	0.06	0	-----	1.43
Aug 2008	53,024,103	5	0.69	4	0.01	2	0.13	1	0.16	0	-----	3	0.01	0	-----	1.04
Sep 2008	250,365,850	6	0.93	2	0.01	0	-----	1	0.05	1	<0.01	2	0.01	0	-----	1.15
May 2009	462,359,684	2	0.42	3	0.45	0	-----	2	0.12	1	<0.01	2	0.01	1	<0.01	1.32
Jun 2009	43,316,391	6	0.74	4	0.05	2	<0.01	1	0.04	1	0.15	0	-----	1	<0.01	1.27
Jul 2009	249,072,218	7	0.66	5	0.08	1	0.06	1	0.14	3	0.01	0	-----	1	0.05	1.93
Aug 2009	271,744,858	11	0.53	8	0.13	1	<0.01	1	0.23	4	0.09	2	0.02	0	-----	2.11
Sep 2009	680,748,032	7	0.36	6	0.11	1	<0.01	2	0.51	4	0.02	1	<0.01	1	<0.01	1.72
Mean*	**268,856,446**	**6.2**	**0.64**	**4.1**	**0.11**	**1.0**	**0.08**	**1.2**	**0.16**	**1.9**	**0.05**	**1.1**	**0.13**	**0.3**	**0.09**	**1.43**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 91. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Sakakawea at site GARLK1445DW during the 5-year period 2005 through 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2005	117,713,953	3	0.66	3	0.21	0	-----	2	0.11	4	0.01	1	<0.01	0	-----	1.50
Jul 2005	72,156,390	5	0.46	2	<0.01	1	0.23	1	0.08	3	0.01	1	0.23	0	-----	1.65
Aug 2005	355,699,437	6	0.73	2	0.05	1	0.01	2	0.07	8	0.15	0	-----	0	-----	1.71
Sep 2005	177,778,515	1	0.08	5	0.36	0	-----	1	0.04	8	0.50	2	0.03	0	-----	1.64
May 2006	494,273,807	7	0.99	1	<0.01	0	-----	2	<0.01	1	<0.01	0	-----	0	-----	1.18
Jun 2006	49,254,498	8	0.73	5	0.08	1	0.02	1	0.17	0	-----	0	-----	0	-----	2.02
Jul 2006	271,528,998	3	0.73	5	0.01	1	<0.01	1	0.22	3	0.03	1	<0.01	0	-----	1.31
Aug 2006	252,320,396	4	0.81	4	0.05	0	-----	1	0.07	1	0.05	1	0.02	0	-----	1.40
Oct 2006	360,297,717	7	0.51	12	0.36	0	-----	1	0.04	6	0.08	1	0.01	0	-----	2.00
May 2007	4,434,931,365	12	0.98	5	0.02	0	-----	1	<0.01	0	-----	0	-----	0	-----	0.59
June 2007	160,826,868	8	0.73	9	0.19	0	-----	2	0.05	0	-----	1	0.02	0	-----	1.45
July 2007	305,880,416	7	0.80	7	0.04	1	0.04	1	0.05	3	0.05	1	0.03	0	-----	1.13
Aug 2007	215,286,031	6	0.34	8	0.16	0	-----	1	0.15	3	<0.01	1	0.33	1	0.01	1.92
Sep 2007	253,797,184	8	0.80	10	0.06	0	-----	1	0.02	4	0.01	1	0.12	0	-----	1.76
May 2008	521,560,198	13	0.90	2	<0.01	0	-----	1	0.10	0	-----	0	-----	0	-----	1.78
Jun 2008	1,111,366,450	9	1.00	4	<0.01	0	-----	1	<0.01	0	-----	0	-----	0	-----	1.31
Jul 2008	130,720	8	0.63	4	0.07	0	0.01	1	0.29	0	-----	0	-----	0	-----	1.33
Aug 2008	628,082,994	6	0.94	3	<0.01	0	-----	1	0.06	2	<0.01	0	-----	0	-----	1.30
Sep 2008	37,854,056	3	0.34	4	0.13	0	-----	1	0.21	2	0.33	0	-----	0	-----	1.68
May 2009	1,282,896,950	6	0.92	3	0.04	1	<0.01	1	0.04	1	<0.01	1	<0.01	0	-----	0.87
Jun 2009	87,769,016	8	0.32	3	0.16	2	0.02	1	0.49	1	<0.01	0	-----	0	-----	1.58
Aug 2009	375,531,574	9	0.31	8	0.25	0	-----	1	0.19	7	0.24	1	<0.01	0	-----	2.00
Sep 2009	614,396,197	6	0.76	6	0.10	0	-----	2	0.11	4	0.03	0	-----	0	-----	1.45
Mean*	**529,623,206**	**6.7**	**0.67**	**5.0**	**0.10**	**0.3**	**0.04**	**1.2**	**0.11**	**2.7**	**0.09**	**0.6**	**0.07**	**0.1**	**0.01**	**1.50**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 92. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Sakakawea at site GARLK1481DW during the 5-year period 2005 through 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2005	162,736,064	4	0.48	6	0.24	0	-----	2	0.23	3	0.01	1	0.03	1	<0.01	2.06
Jul 2005	45,637,096	3	0.95	3	0.04	0	-----	1	0.01	1	<0.01	0	-----	0	-----	1.26
Aug 2005	123,071,200	4	0.52	6	0.13	0	-----	2	0.16	5	0.05	2	0.14	0	-----	1.80
Sep 2005	136,453,161	10	0.30	10	0.47	0	-----	2	0.10	8	0.07	1	0.04	1	0.02	2.07
May 2006	350,014,023	10	0.90	9	0.03	2	0.01	1	<0.01	1	<0.01	2	0.04	3	0.01	2.06
Jun 2006	271,464,027	8	0.96	4	0.02	0	-----	1	<0.01	1	0.01	0	-----	1	<0.01	0.99
Jul 2006	109,852,109	7	0.29	7	0.11	1	0.02	1	0.49	3	0.05	1	0.03	0	-----	1.96
Aug 2006	226,689,591	8	0.36	13	0.25	1	0.01	1	0.06	3	0.26	2	0.05	3	0.02	2.69
Oct 2006	1,395,049,142	10	0.78	17	0.05	2	0.03	2	0.01	6	0.12	2	0.01	2	0.01	2.16
May 2007	2,999,852,220	11	0.89	7	0.11	0	-----	1	0.01	0	-----	0	-----	0	-----	0.93
June 2007	513,050,143	10	0.87	7	0.10	0	-----	1	0.02	1	<0.01	0	-----	0	-----	1.29
July 2007	254,413,324	9	0.13	6	0.11	1	<0.01	1	0.13	4	0.62	1	0.02	0	-----	2.01
Aug 2007	222,884,487	8	0.33	8	0.16	1	<0.01	1	0.15	5	0.03	1	0.32	2	0.01	2.05
Sep 2007	918,618,938	10	0.82	12	0.04	1	0.01	2	0.01	4	0.06	2	0.04	2	0.02	2.02
May 2008	1,419,301,364	12	0.99	2	<0.01	1	0.01	1	<0.01	1	<0.01	0	-----	1	<0.01	1.62
Jun 2008	357,464,958	10	1.00	1	<0.01	0	-----	1	<0.01	0	-----	0	-----	0	<0.01	1.45
Jul 2008	172,911	7	0.90	3	<0.01	0	-----	1	0.08	0	-----	1	<0.01	1	0.01	1.60
Aug 2008	856,371,701	7	0.87	7	0.08	2	<0.01	1	0.03	4	<0.01	2	0.01	2	<0.01	1.57
Sep 2008	1,278,523,241	5	0.95	6	0.02	1	<0.01	1	0.02	5	0.01	1	<0.01	1	<0.01	0.78
May 2009	1,760,126,834	12	0.87	4	0.02	1	<0.01	2	0.11	2	<0.01	1	<0.01	0	-----	1.34
Jun 2009	4,120,481,803	12	0.61	4	0.28	2	<0.01	1	0.10	3	0.01	1	<0.01	0	-----	1.48
Jul 2009	1,738,714,499	9	0.80	7	0.04	1	<0.01	1	0.08	3	<0.01	2	<0.01	0	-----	1.44
Aug 2009	3,383,196,129	8	0.32	7	0.02	2	<0.01	2	0.10	2	<0.01	1	0.56	0	-----	1.35
Sep 2009	1,360,560,569	12	0.68	8	0.02	1	<0.01	2	0.27	5	0.03	1	<0.01	0	-----	1.41
Mean*	**1,000,195,814**	**8.6**	**0.69**	**6.8**	**0.10**	**0.8**	**0.02**	**1.3**	**0.09**	**2.9**	**0.06**	**1.0**	**0.07**	**0.8**	**0.01**	**1.64**

* Mean percent composition represents the mean when taxa of that division are present.

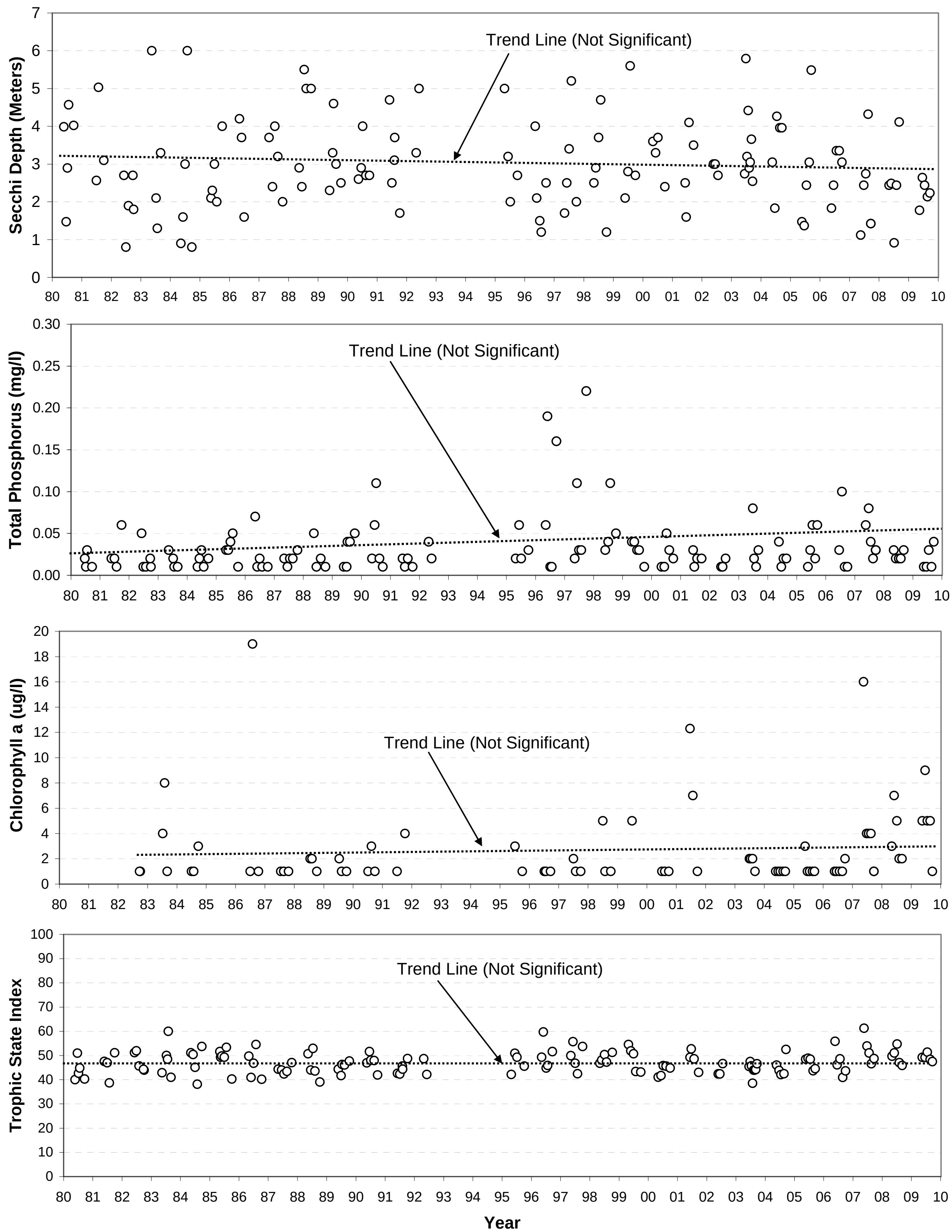


Plate 93. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Lake Sakakawea at the near-dam, ambient site (i.e., site GARLK1390A) over the 30-year period of 1980 through 2009.

Plate 94. Summary of monthly (April through September) water quality conditions monitored in the Missouri River near Williston, North Dakota at monitoring site GARNFMORRR1 during the 5-year period 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	28	20,282	14,445	7,649	52,320	-----	-----	-----
Water Temperature (°C)	0.1	28	19.6	20.3	9.4	30.9	29.4[1,2]	1	4%
Dissolved Oxygen (mg/l)	0.1	28	8.5	8.3	6.8	10.2	5[1,3]	0	0%
Dissolved Oxygen (% Sat.)	0.1	28	95.7	95.2	78.1	105.1	-----	-----	-----
pH (S.U.)	0.1	28	8.4	8.4	7.9	9.0	7.0[1,3], 9.0[1,2]	0	0%
Specific Conductance (umho/cm)	1	28	538	567	292	728	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	28	327	323	236	415	-----	-----	-----
Turbidity (NTU)	1	28	286	110	6	1,234	-----	-----	-----
Alkalinity, Total (mg/l)	7	28	141	148	90	174	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	27	2.9	2.9	1.5	5.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	24	17	12	3	93	-----	-----	-----
Chloride, Dissolved (mg/l)	1	23	9	9	4	17	100[1,2]	0	0%
Dissolved Solids, Total (mg/l)	5	27	391	387	214	633	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	28	-----	0.03	n.d.	0.21	3.9 [1,2,4], 0.84 [1,4,5]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	28	0.8	0.6	0.1	2.1	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	28	-----	0.02	n.d.	0.30	1.0[1,2]	0	0%
Nitrogen, Total (mg/l)	0.1	28	0.9	0.6	0.2	2.1	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	27	-----	0.02	n.d.	0.15	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	28	0.30	0.19	0.04	1.10	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	28	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	28	139	150	64	196	250[1,2]	0	0%
Suspended Solids, Total (mg/l)	4	28	355	157	37	2,156	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for Class 1 streams.

(2) Daily maximum criterion (monitoring results directly comparable to criterion).

(3) Daily minimum criterion (monitoring results directly comparable to criterion).

(4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(5) 30-day average criterion (monitoring results not directly comparable to criterion).

Plate 95. Summary of annual metals and pesticide levels monitored in the Missouri River near Williston, North Dakota at monitoring site GARNFMORRR1 during the 5-year period 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	3	-----	n.d.	n.d.	50	-----	-----	-----
Aluminum, Total (ug/l)	25	3	5,184	4,560	3,001	7,990	750(6)	3	100%
Antimony, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Antimony, Total (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	5.6(8)	0	0%
Arsenic, Dissolved (ug/l)	1	3	2	2	2	3	-----	-----	-----
Arsenic, Total (ug/l)	1	3	5	4	4	6	340(1), 150(2), 10(3)	0	0%
Barium, Dissolved (ug/l)	5	3	51	51	48	53	-----	-----	-----
Barium, Total (ug/l)	5	3	74	81	50	90	1,000(8)	0	0%
Beryllium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Beryllium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	4(8)	0	0%
Cadmium, Dissolved (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Cadmium, Total (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	4.3(6), 0.45(7), 5(8)	0	0%
Chromium, Dissolved (ug/l)	10	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Chromium, Total (ug/l)	10	3	-----	n.d.	n.d.	10	3,168(6), 151(7), 100(8)	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Copper, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	27(6), 17(7), 1,000(8)	0	0%
Hardness, Total (mg/l)	0.4	4	203	199	181	231	-----	-----	-----
Iron, Dissolved (ug/l)	40	14(A)	-----	n.d.	n.d.	50	-----	-----	-----
Iron, Total (ug/l)	40	13(A)	9,144	6,812	1,979	32,066	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Lead, Total (ug/l)	0.5	3	3.3	3.0	3.0	4.0	196(6), 7.6(7), 15(8)	0	0%
Manganese, Dissolved (ug/l)	2	14(A)	-----	2	n.d.	30	-----	-----	-----
Manganese, Total (ug/l)	2	13(A)	204	139	54	629	-----	-----	-----
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	1.7(6), 0.012(7), 0.05(8)	0, b.d., 0	0%
Nickel, Dissolved (ug/l)	10	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Nickel, Total (ug/l)	10	3	-----	n.d.	n.d.	10	840(6), 93(7), 100(8)	0	0%
Selenium, Total (ug/l)	1	2	1	1	1	1	20(6), 5(7), 50(8)	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Silver, Total (ug/l)	1	3	-----	n.d.	n.d.	n.d.	14(6)	0	0%
Thallium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Total (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	0.24(7)	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Zinc, Total (ug/l)	10	3	38	20	13	80	215(6,7), 7,400(8)	0	0%
Pesticide Scan (ug/l)(D)	0.05	4	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for Class 1 streams.
- (2) Daily maximum criterion (monitoring results directly comparable to criterion).
- (3) Daily minimum criterion (monitoring results directly comparable to criterion).
- (4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (5) 30-day average criterion (monitoring results not directly comparable to criterion).
- (6) Acute criterion for aquatic life.
- (7) Chronic criterion for aquatic life.
- (8) Human health criterion for surface waters.

Note: Some of North Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

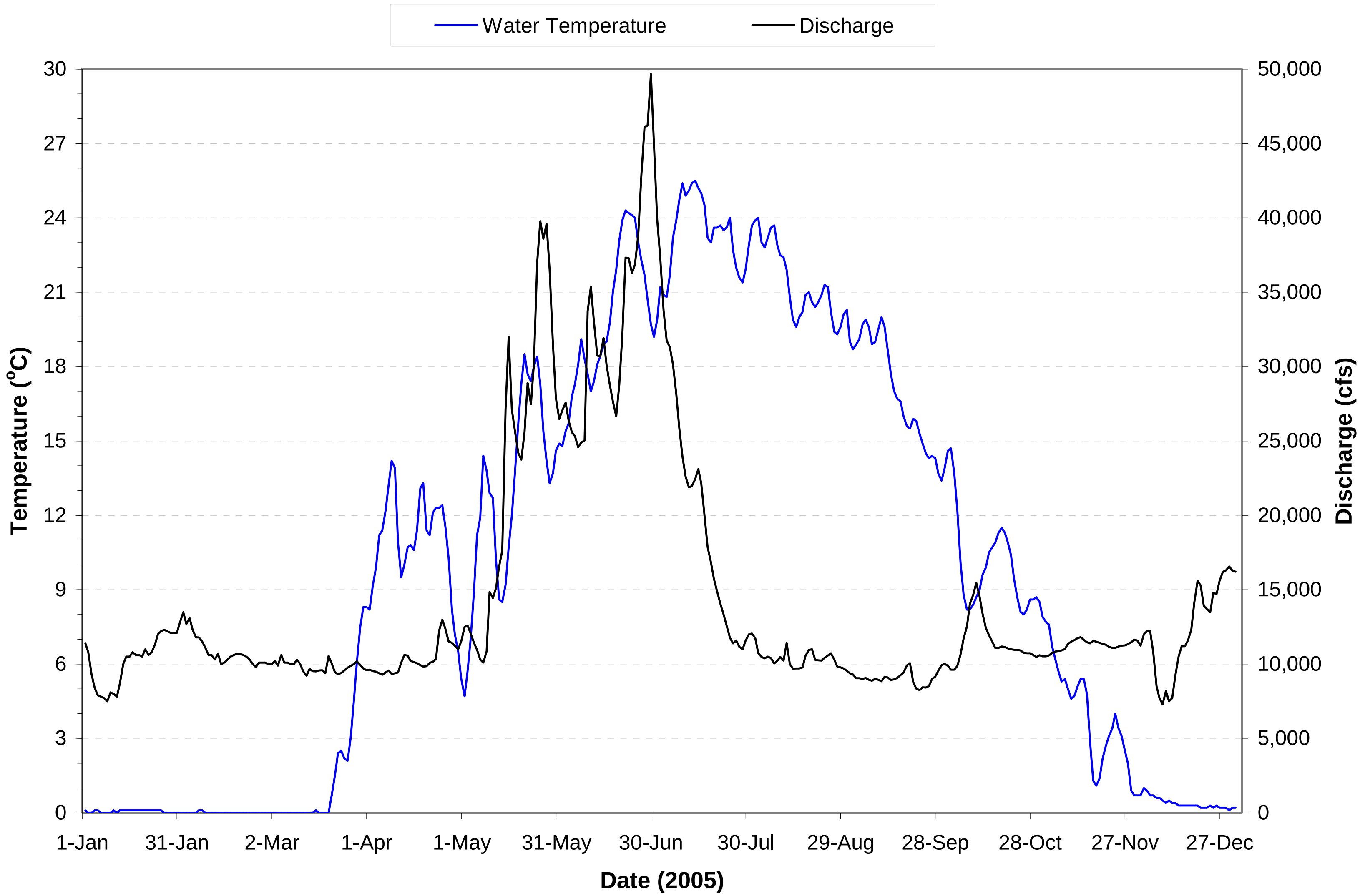


Plate 96. Mean daily water temperature and discharge of the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) for 2005. Mean temperatures based on hourly measurements recorded on the Missouri River near Williston, North Dakota (USGS gaging station 06330000). Mean daily discharge estimated by adding mean daily discharge recorded for the Missouri River near Culbertson, Montana (USGS gaging station 06185500) and the mean daily discharge recorded for the Yellowstone River near Sidney, Montana (USGS gaging station 06329500).

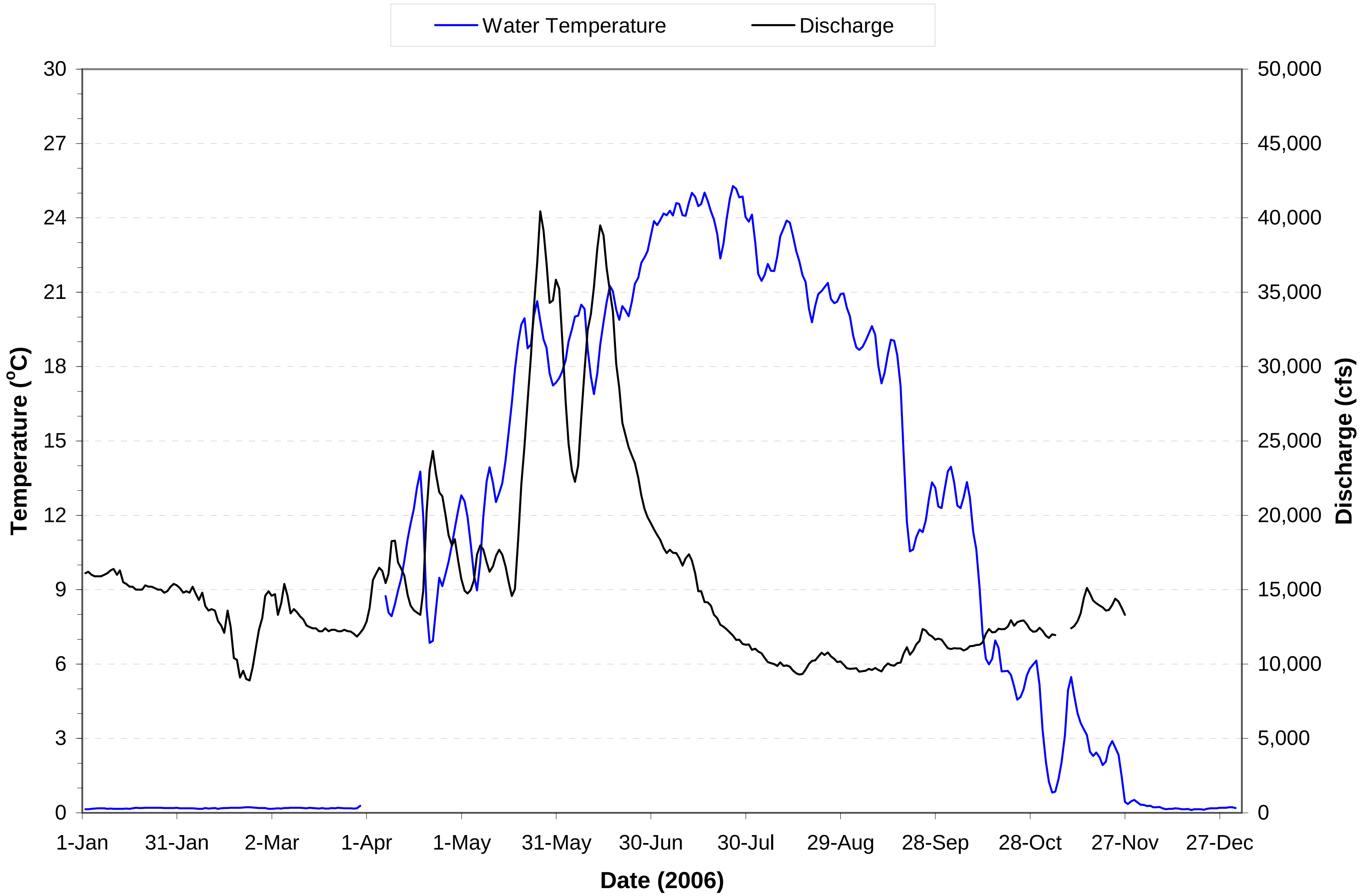


Plate 97. Mean daily water temperature and discharge of the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) for 2006. Mean temperatures based on hourly measurements recorded on the Missouri River near Williston, North Dakota (USGS gaging station 06330000). Mean daily discharge estimated by adding mean daily discharge recorded for the Missouri River near Culbertson, Montana (USGS gaging station 06185500) and the mean daily discharge recorded for the Yellowstone River near Sidney, Montana (USGS gaging station 06329500).

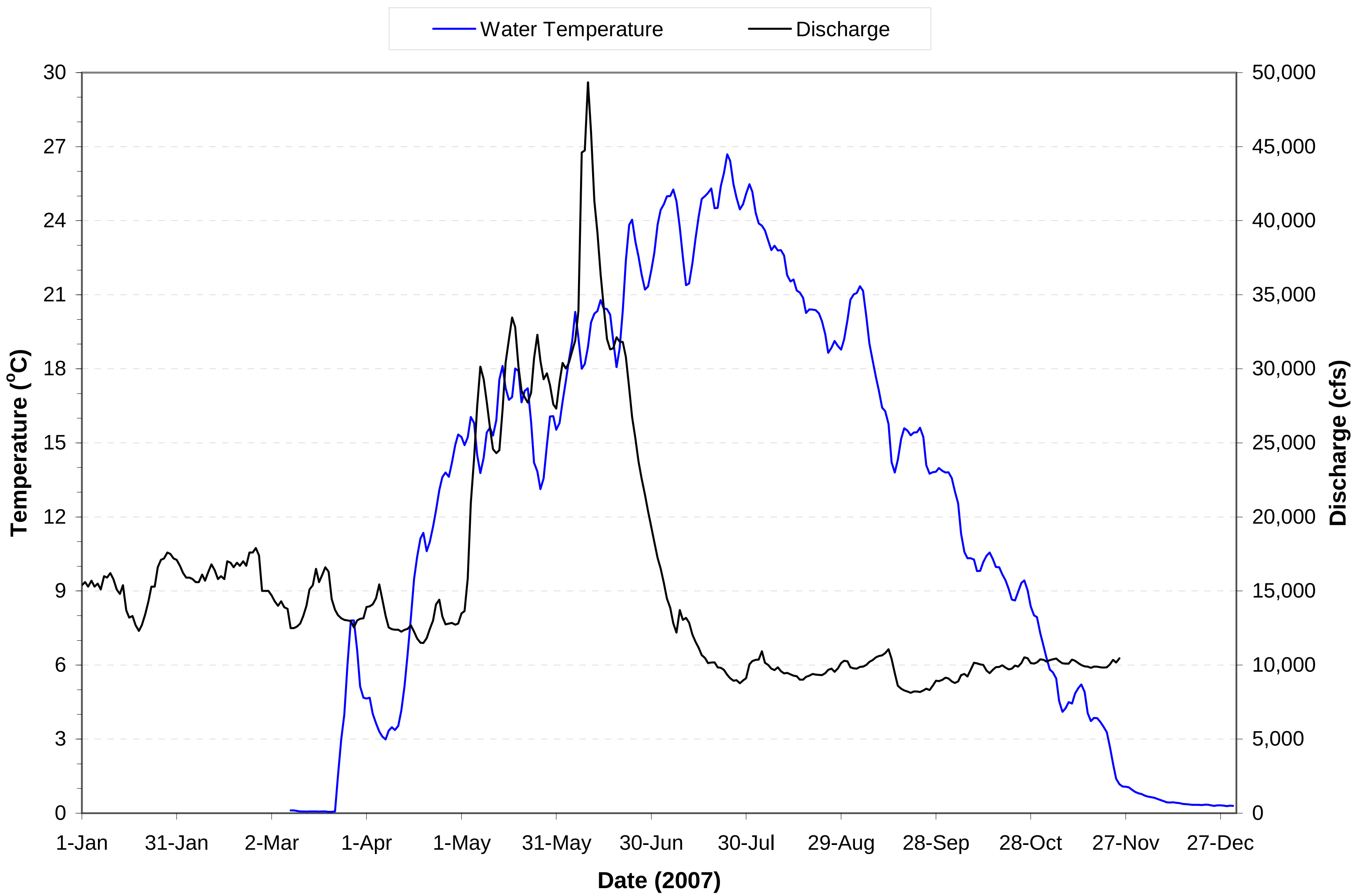


Plate 98. Mean daily water temperature and discharge of the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) for 2007. Mean temperatures based on hourly measurements recorded on the Missouri River near Williston, North Dakota (USGS gaging station 06330000). Mean daily discharge estimated by adding mean daily discharge recorded for the Missouri River near Culbertson, Montana (USGS gaging station 06185500) and the mean daily discharge recorded for the Yellowstone River near Sidney, Montana (USGS gaging station 06329500).

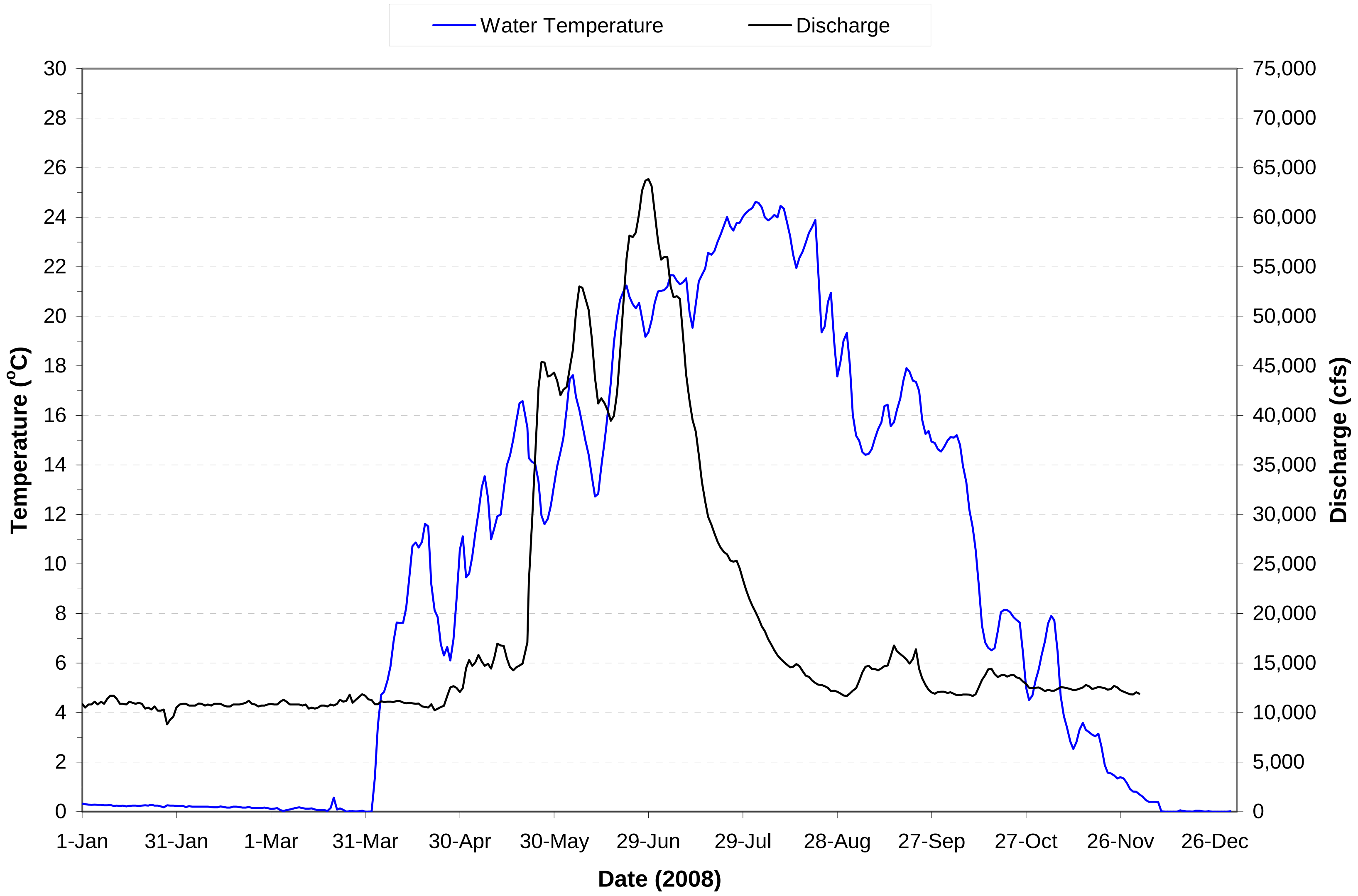


Plate 99. Mean daily water temperature and discharge of the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) for 2008. Mean temperatures based on hourly measurements recorded on the Missouri River near Williston, North Dakota (USGS gaging station 06330000). Mean daily discharge estimated by adding mean daily discharge recorded for the Missouri River near Culbertson, Montana (USGS gaging station 06185500) and the mean daily discharge recorded for the Yellowstone River near Sidney, Montana (USGS gaging station 06329500).

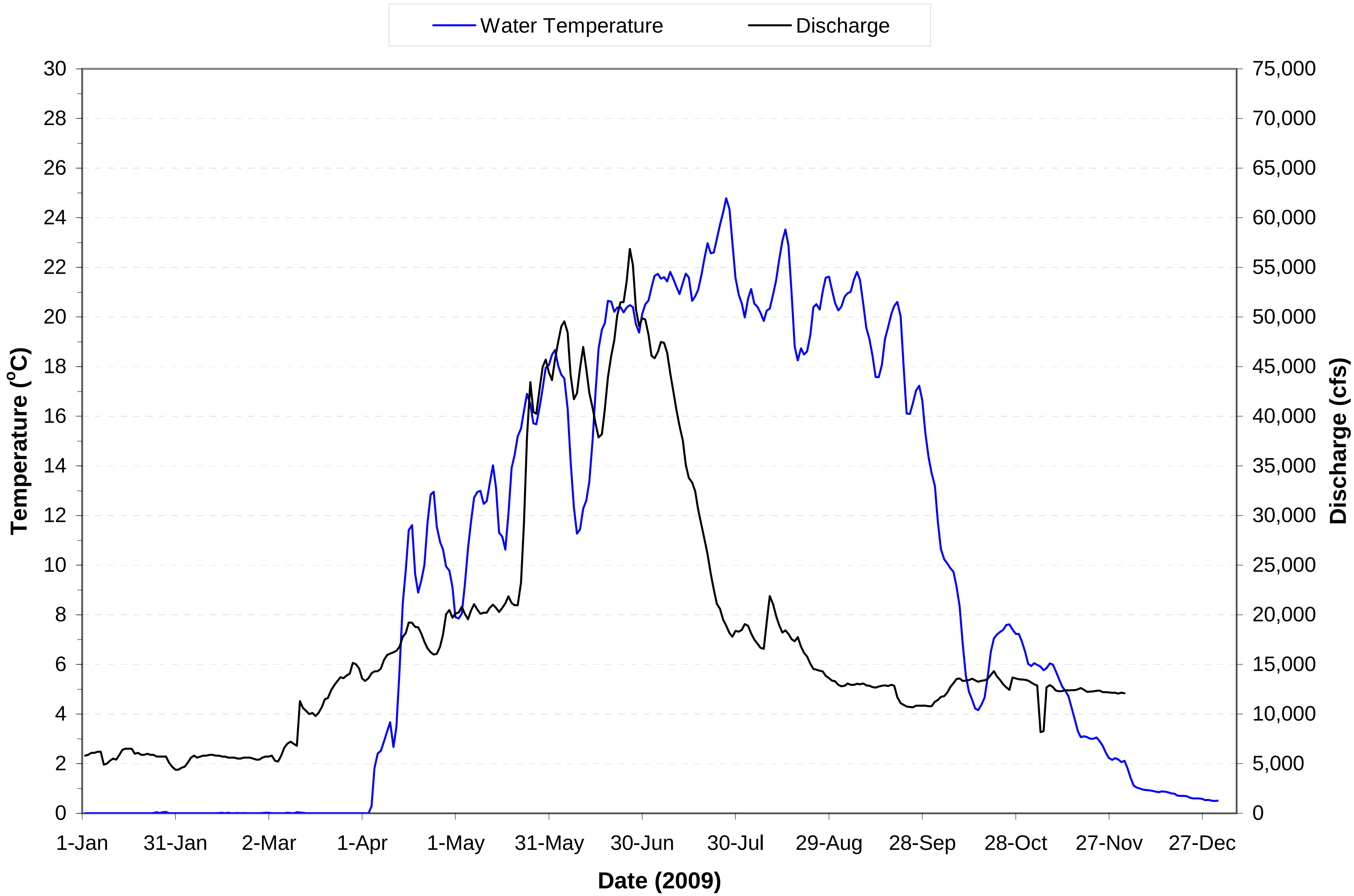


Plate 100. Mean daily water temperature and discharge of the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) for 2009. Mean temperatures based on hourly measurements recorded on the Missouri River near Williston, North Dakota (USGS gaging station 06330000). Mean daily discharge estimated by adding mean daily discharge recorded for the Missouri River near Culbertson, Montana (USGS gaging station 06185500) and the mean daily discharge recorded for the Yellowstone River near Sidney, Montana (USGS gaging station 06329500).

Plate 101. Summary of monthly water quality conditions monitored from water discharged through Garrison Dam (i.e., GARPP1) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	53	15,989	13,528	9,402	37,300	-----	-----	-----
Water Temperature (°C)	0.1	47	8.3	8.1	1.0	18.2	29.4(1,2)	0	0%
Dissolved Oxygen (mg/l)	0.1	46	10.3	10.8	5.2	14.2	5(1,3)	0	0%
Dissolved Oxygen (% Sat.)	0.1	46	89.4	92.8	56.0	105.6	-----	-----	-----
pH (S.U.)	0.1	42	8.1	8.1	7.3	8.9	7.0(1,3), 9.0(1,2)	0	0%
Specific Conductance (umho/cm)	1	46	591	595	481	815	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	32	390	372	328	548	-----	-----	-----
Turbidity (NTU)	1	32	4	2	n.d.	19	-----	-----	-----
Alkalinity, Total (mg/l)	7	52	159	156	140	186	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	49	3.1	3.1	1.3	7.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	41	7	7	n.d.	16	-----	-----	-----
Chloride, Dissolved (mg/l)	1	39	9	10	n.d.	12	100(1,2)	0	0%
Dissolved Solids, Total (mg/l)	5	52	409	409	236	516	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	52	-----	n.d.	n.d.	0.23	6.9 (1,2,4), 2.0 (1,4,5)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	51	0.4	0.3	n.d.	2.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	52	-----	0.07	n.d.	0.20	1.0(1,2)	0	0%
Nitrogen, Total (mg/l)	0.1	51	0.5	0.4	n.d.	2.4	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	44	-----	n.d.	n.d.	0.05	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	52	-----	0.02	n.d.	0.30	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	52	-----	n.d.	n.d.	0.25	-----	-----	-----
Sulfate (mg/l)	1	52	160	159	128	190	250(1,2)	0	0%
Suspended Solids, Total (mg/l)	4	52	-----	n.d.	n.d.	21	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for Class 1 streams.
- (2) Daily maximum criterion (monitoring results directly comparable to criterion).
- (3) Daily minimum criterion (monitoring results directly comparable to criterion).
- (4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (5) 30-day average criterion (monitoring results not directly comparable to criterion).

Plate 102. Summary of monthly water quality conditions monitored from water discharged through Garrison Dam (i.e., GARPP1) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Aluminum, Total (ug/l)	25	3	88	94	60	110	750[6]	0	0%
Antimony, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	0.6	-----	-----	-----
Antimony, Total (ug/l)	0.5	3	-----	n.d.	n.d.	0.5	5.6[8]	0	0%
Arsenic, Dissolved (ug/l)	1	3	-----	1	n.d.	2	-----	-----	-----
Arsenic, Total (ug/l)	1	3	1	1	1	2	340[1], 150[2], 10[3]	0	0%
Barium, Dissolved (ug/l)	5	3	52	50	49	58	-----	-----	-----
Barium, Total (ug/l)	5	3	54	52	50	60	1,000[8]	0	0%
Beryllium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Beryllium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	4[8]	0	0%
Cadmium, Dissolved (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Cadmium, Total (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	4.4[6], 0.46[7], 5[8]	0	0%
Chromium, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Chromium, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	3,207[6], 153[7], 100[8]	0	0%
Copper, Dissolved (ug/l)	2	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Copper, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	27[6], 17[7], 1,000[8]	0	0%
Hardness, Total (mg/l)	0.4	4	203	202	186	223	-----	-----	-----
Iron, Dissolved (ug/l)	40	25[A]	-----	n.d.	n.d.	10	-----	-----	-----
Iron, Total (ug/l)	40	26[A]	189	90	n.d.	1,401	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Lead, Total (ug/l)	0.5	3	-----	n.d.	n.d.	0.7	200[6], 7.8[7], 15[8]	0	0%
Manganese, Dissolved (ug/l)	2	26[A]	-----	1	n.d.	12	-----	-----	-----
Manganese, Total (ug/l)	2	26[A]	9	7	n.d.	64	-----	-----	-----
Mercury, Dissolved (ug/l)	0.02	7	-----	n.d.	n.d.	n.d.	-----	-----	-----
Mercury, Total (ug/l)	0.02	7	-----	n.d.	n.d.	n.d.	1.7[6], 0.012[7], 0.05[8]	0, b.d., 0	0%
Nickel, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Nickel, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	850[6], 95[7], 100[8]	0	0%
Selenium, Total (ug/l)	1	6	-----	n.d.	n.d.	2	20[6], 5[7], 50[8]	0	0%
Silver, Dissolved (ug/l)	1	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Silver, Total (ug/l)	1	3	-----	n.d.	n.d.	n.d.	14[6]	0	0%
Thallium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Total (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	0.24[7]	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Zinc, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	217[6,7], 7,400[8]	0	0%
Pesticide Scan (ug/l)[D]	0.05	4	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

[A] Results for iron (dissolved and total) and manganese (dissolved and total) include some monthly samples.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for Class 1 streams.
- [2] Daily maximum criterion (monitoring results directly comparable to criterion).
- [3] Daily minimum criterion (monitoring results directly comparable to criterion).
- [4] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- [5] 30-day average criterion (monitoring results not directly comparable to criterion).
- [6] Acute criterion for aquatic life.
- [7] Chronic criterion for aquatic life.
- [8] Human health criterion for surface waters.

Note: Some of North Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

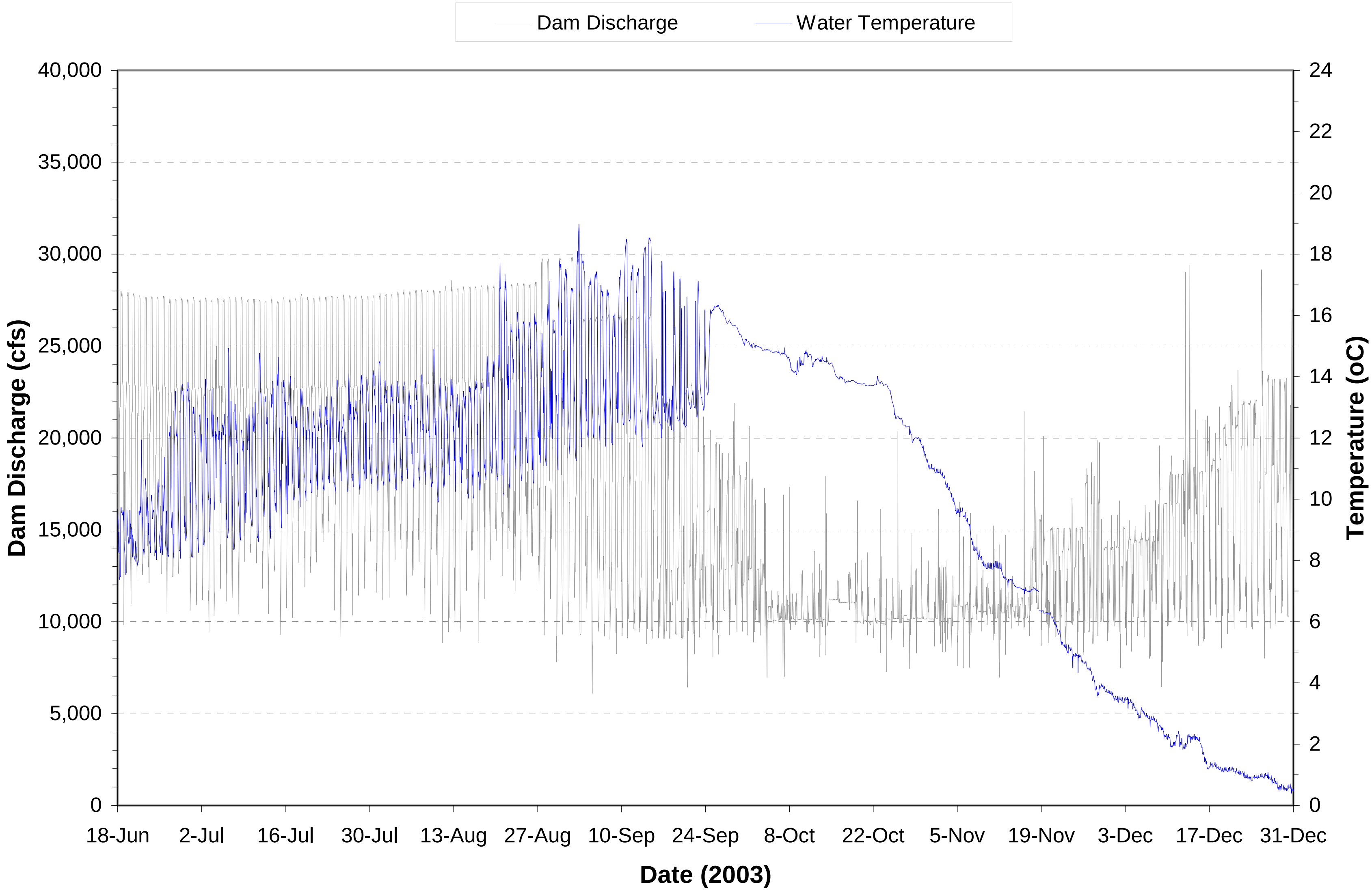


Plate 103. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period June through December 2003.

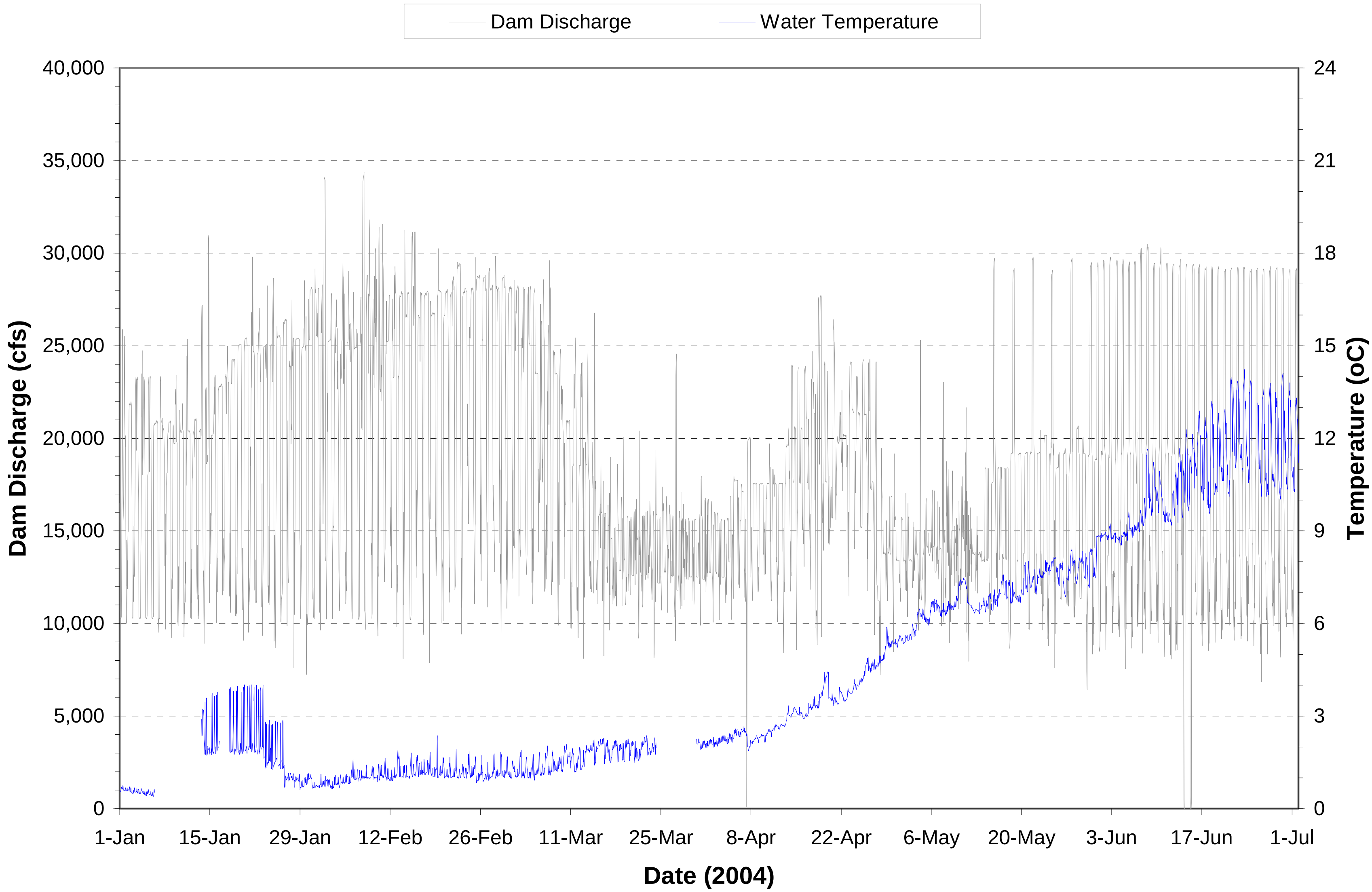


Plate 104. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2004.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

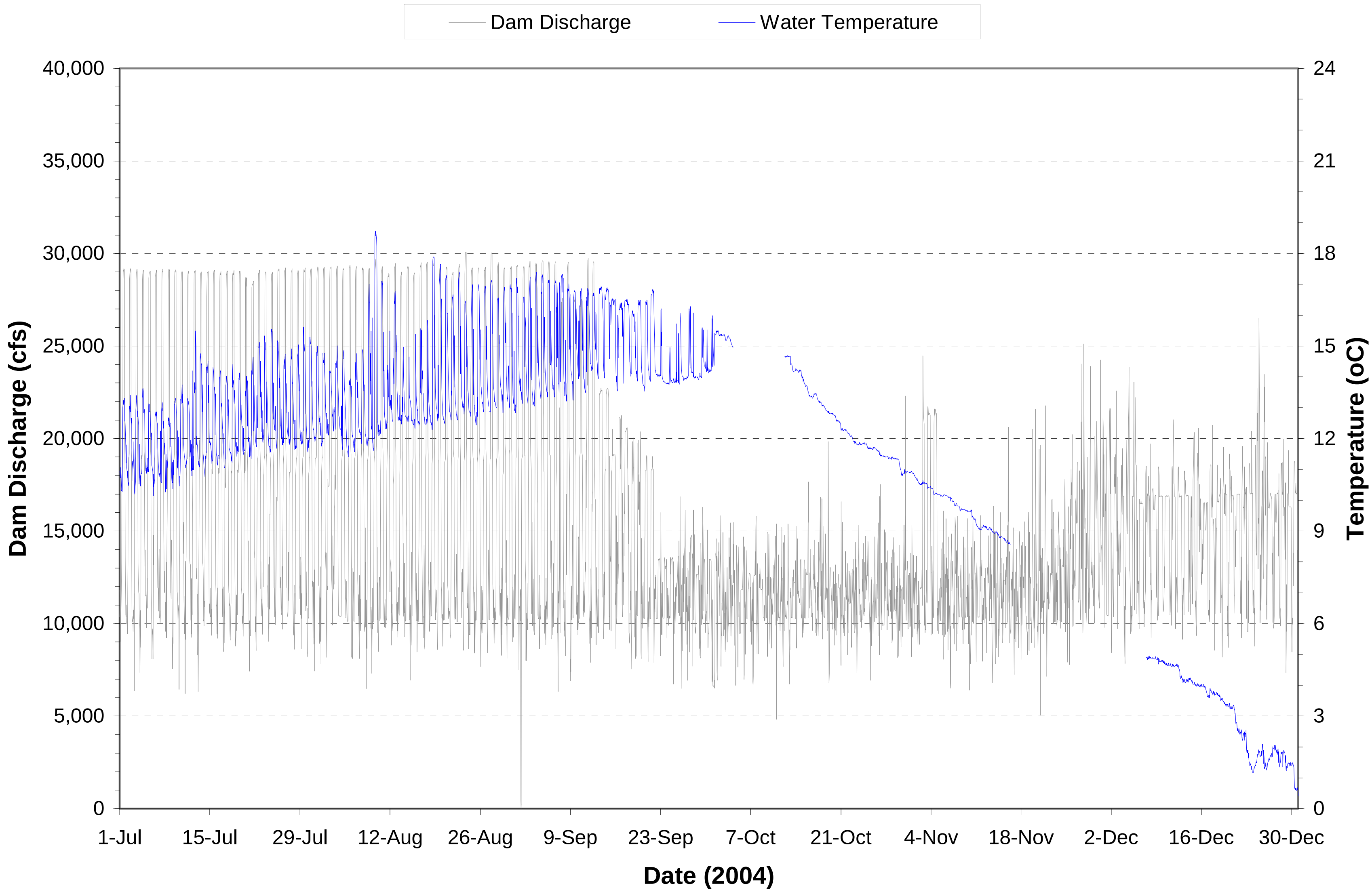


Plate 105. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2004.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

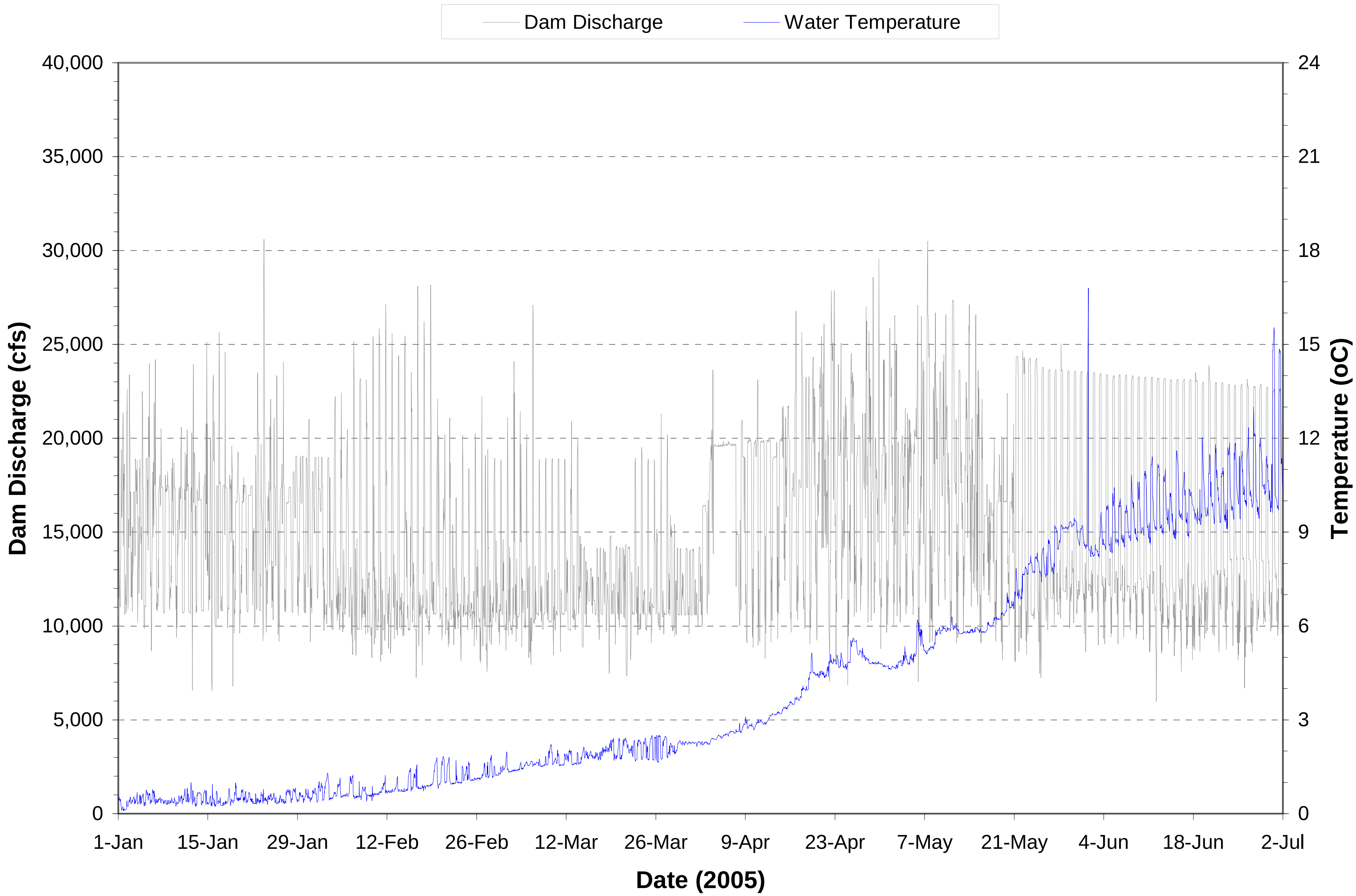


Plate 106. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2005.

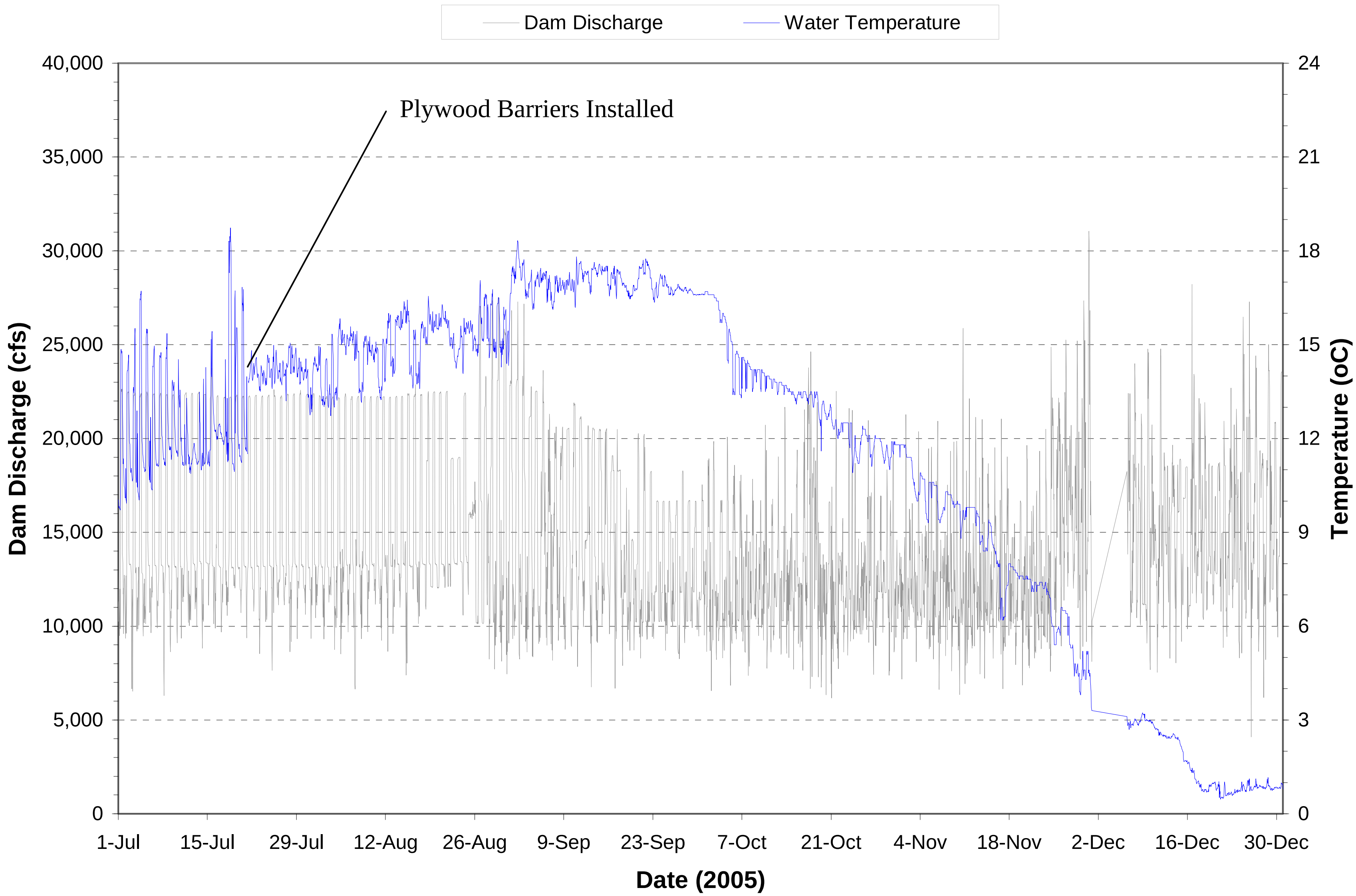


Plate 107. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2005.

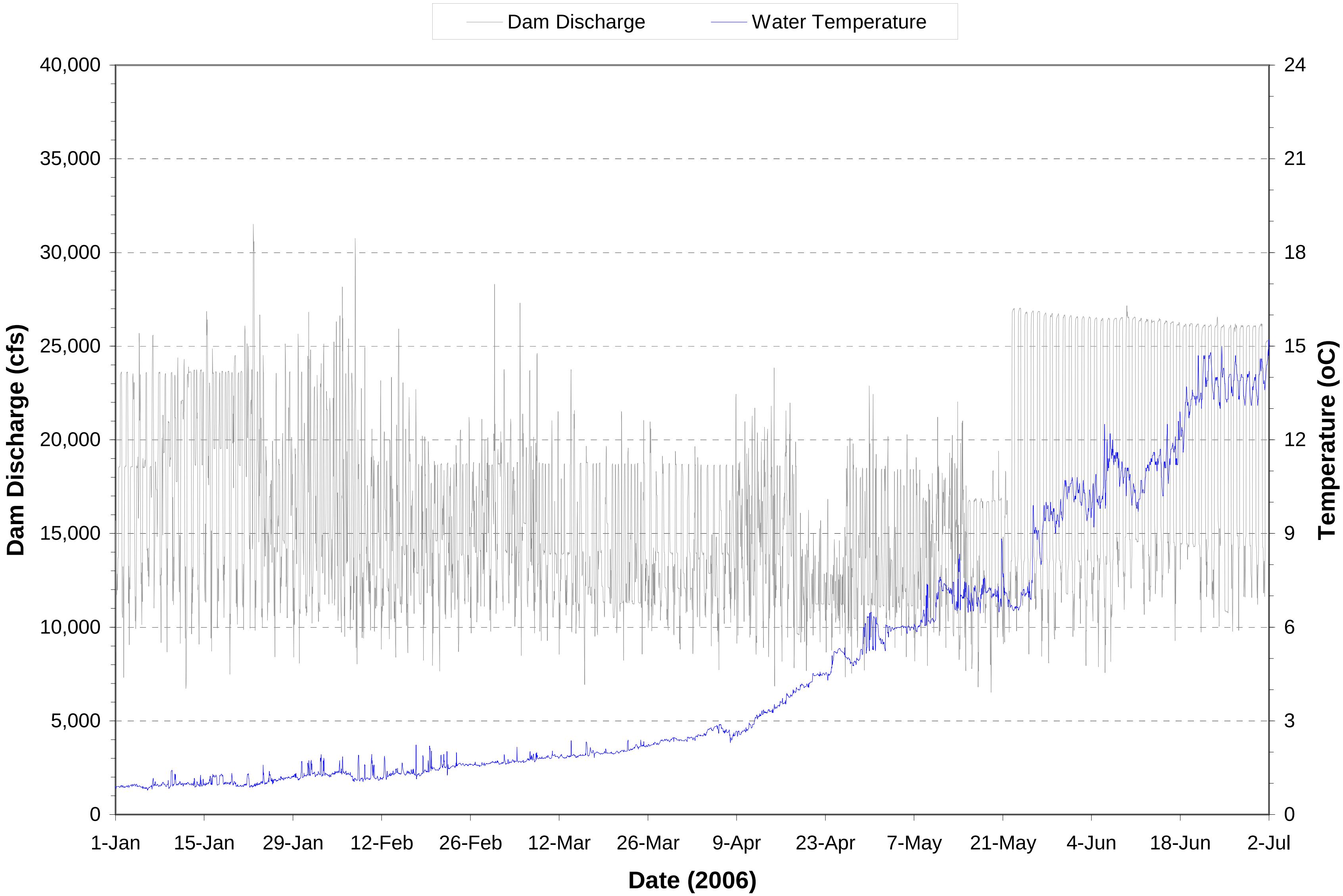


Plate 108. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2006.

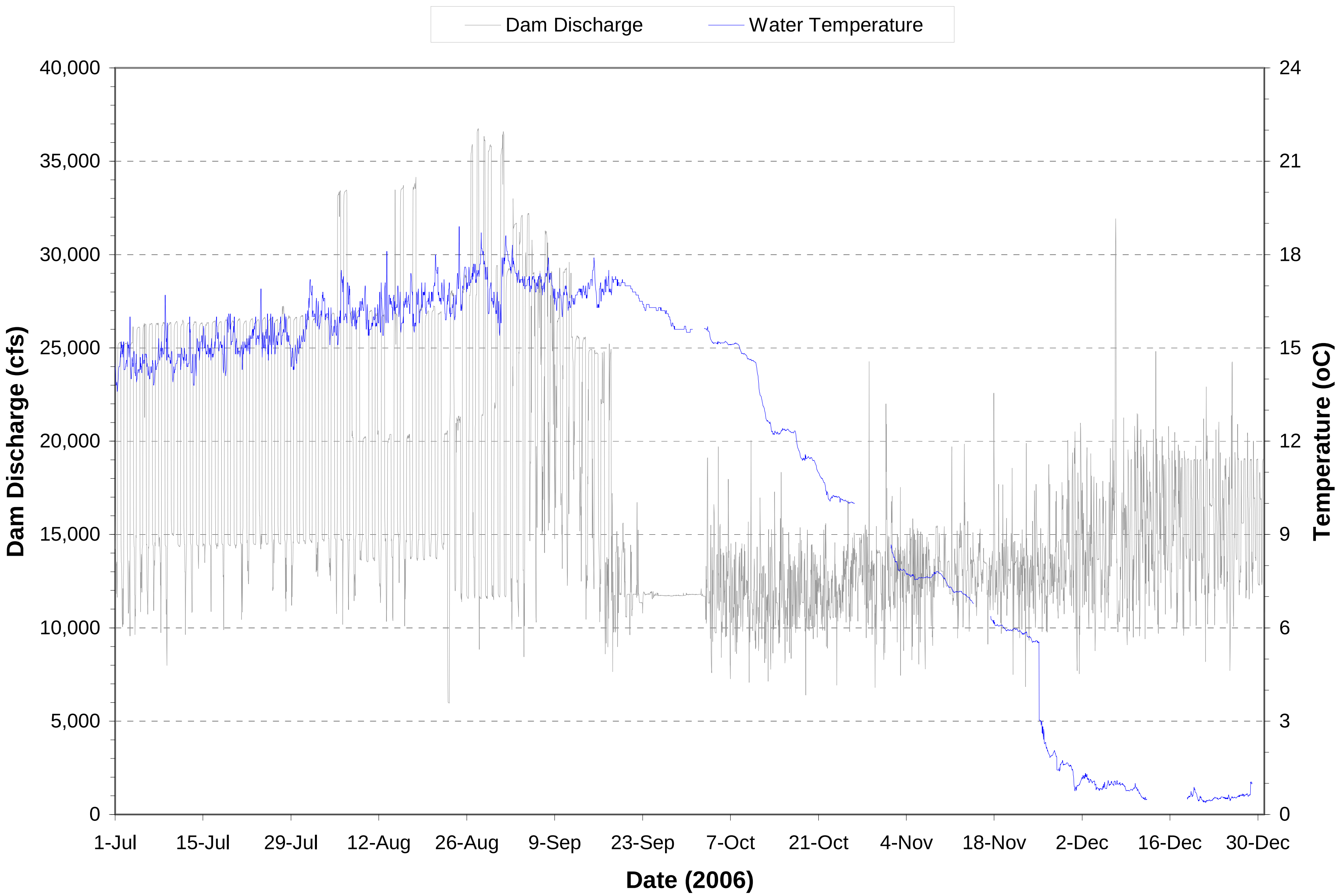


Plate 109. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

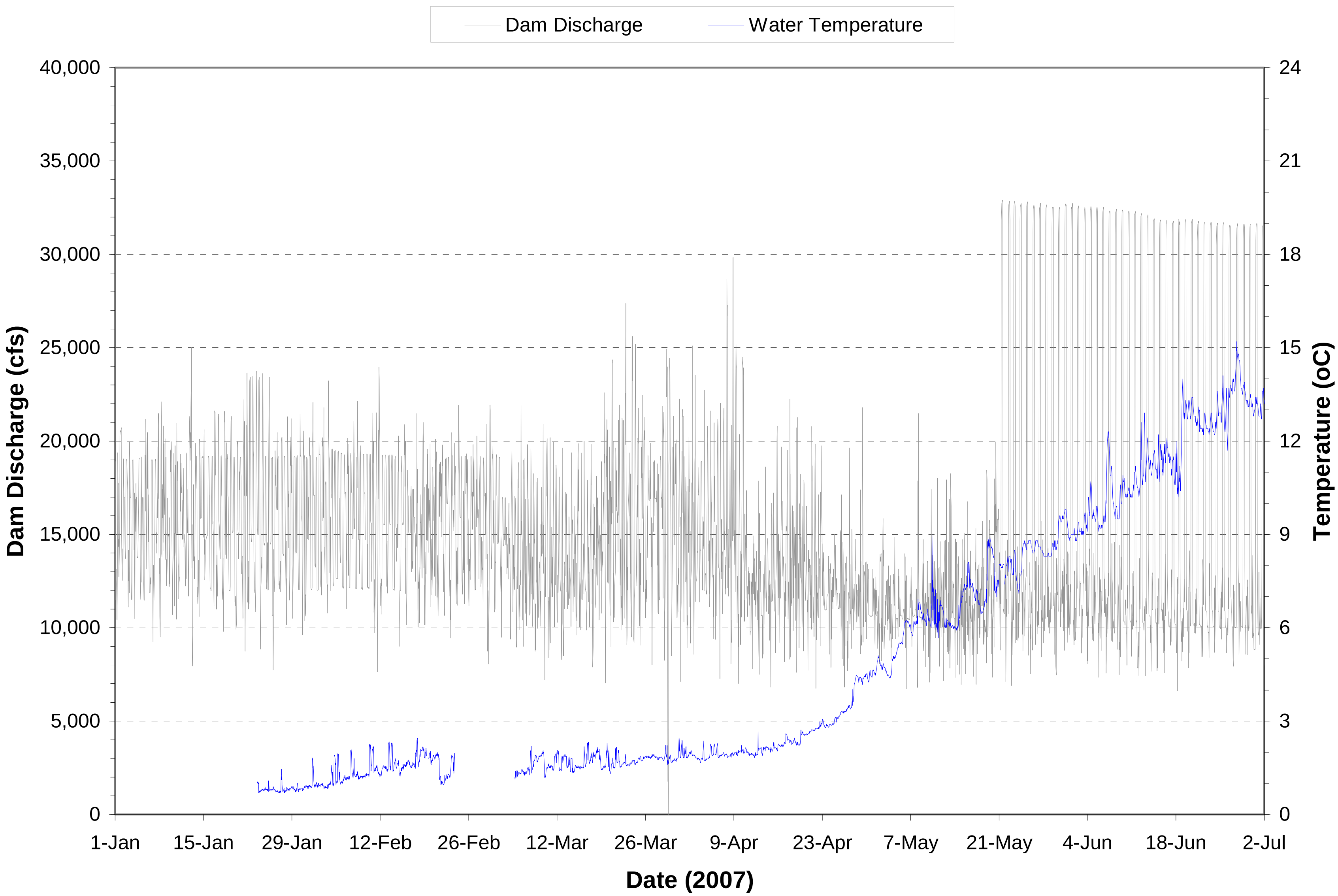


Plate 110. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2007.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

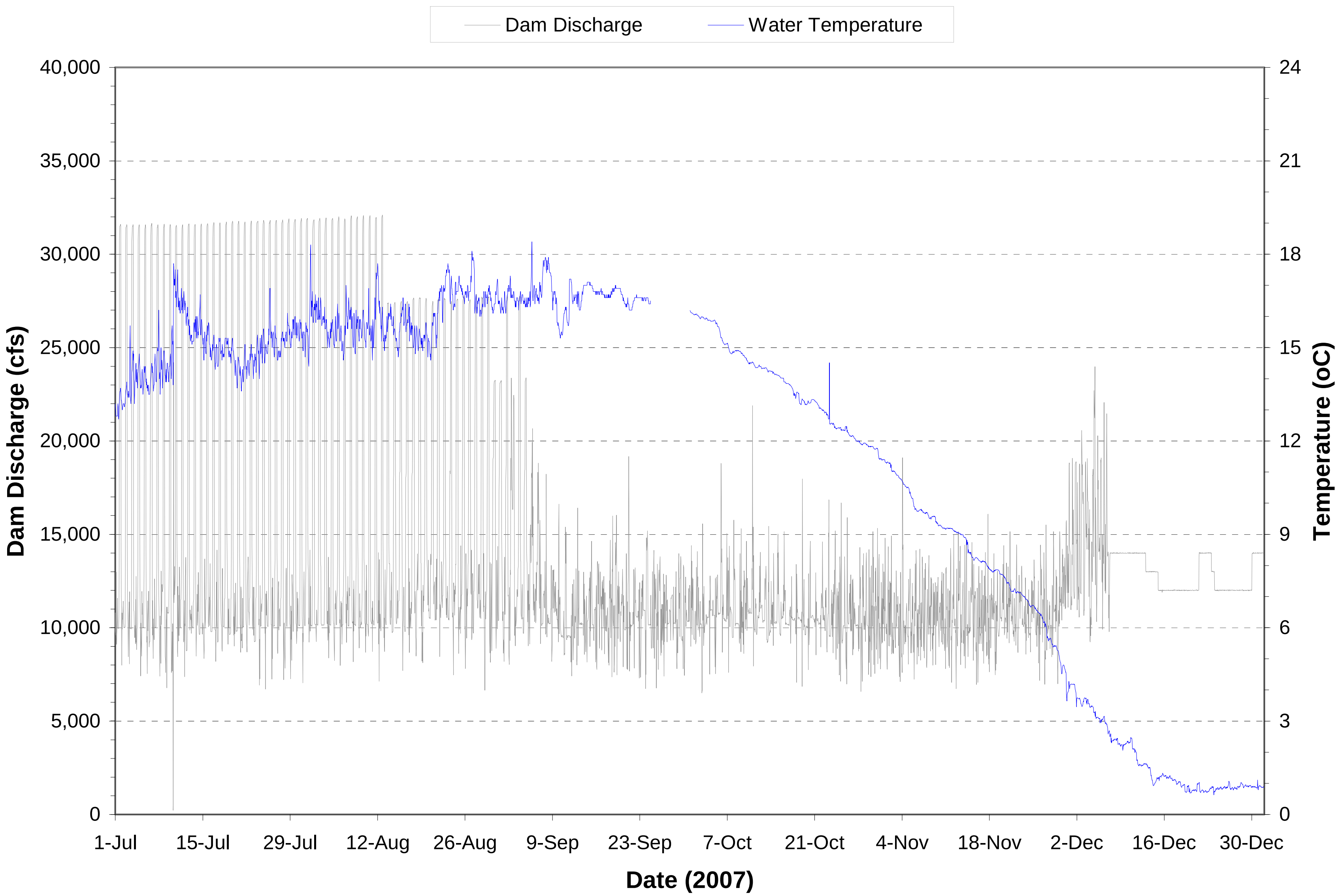


Plate 111. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

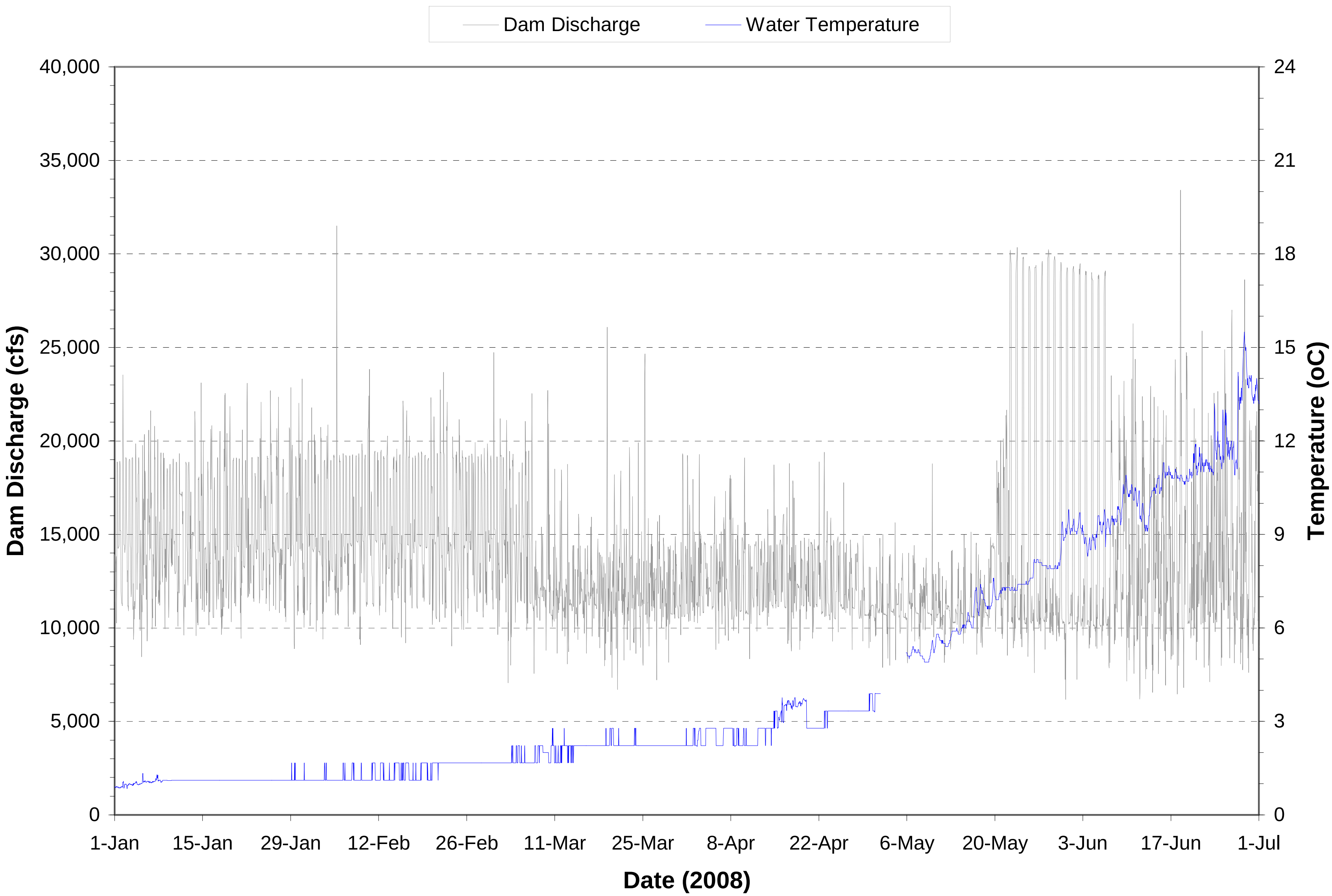


Plate 112. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2008.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

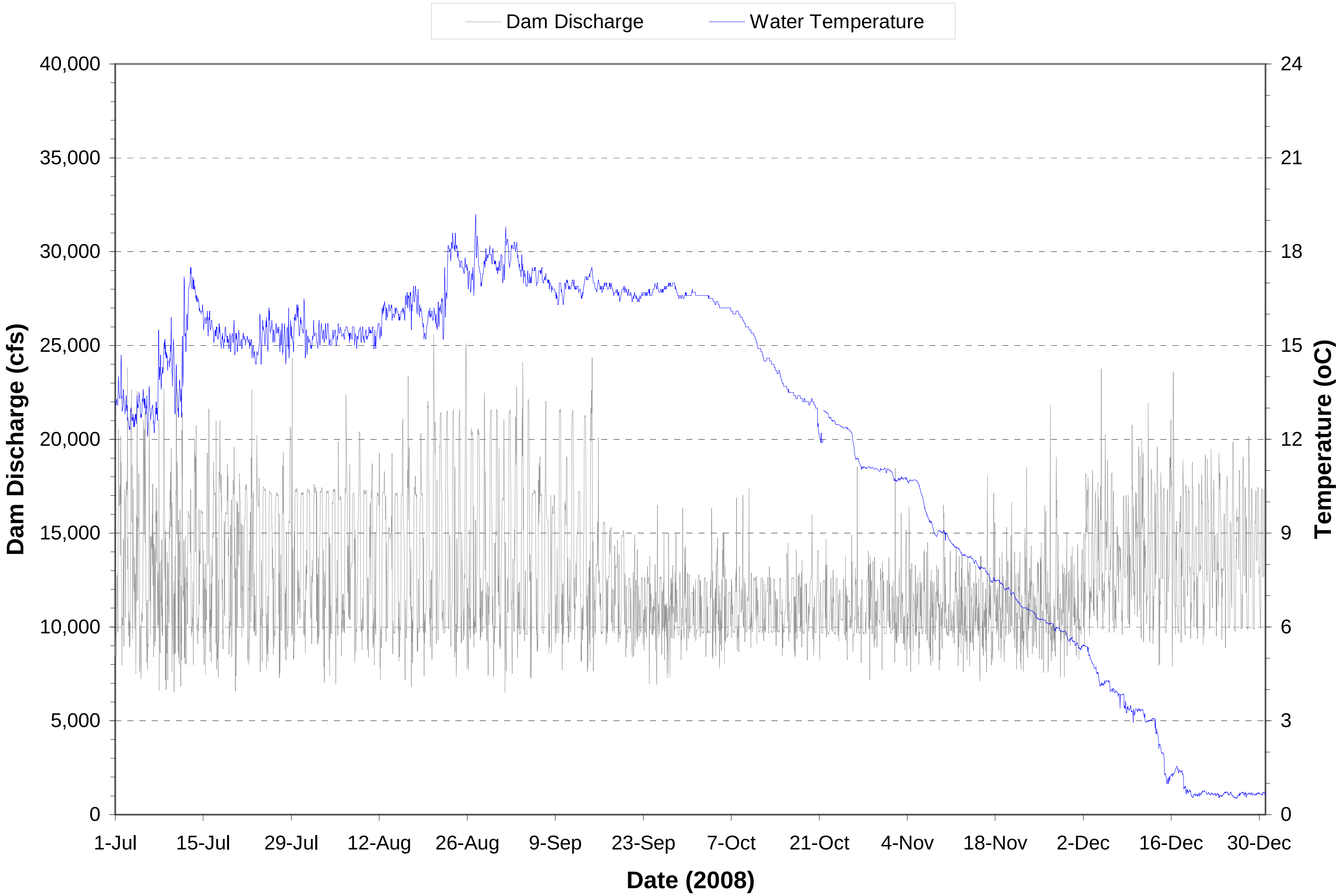


Plate 113. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2008.

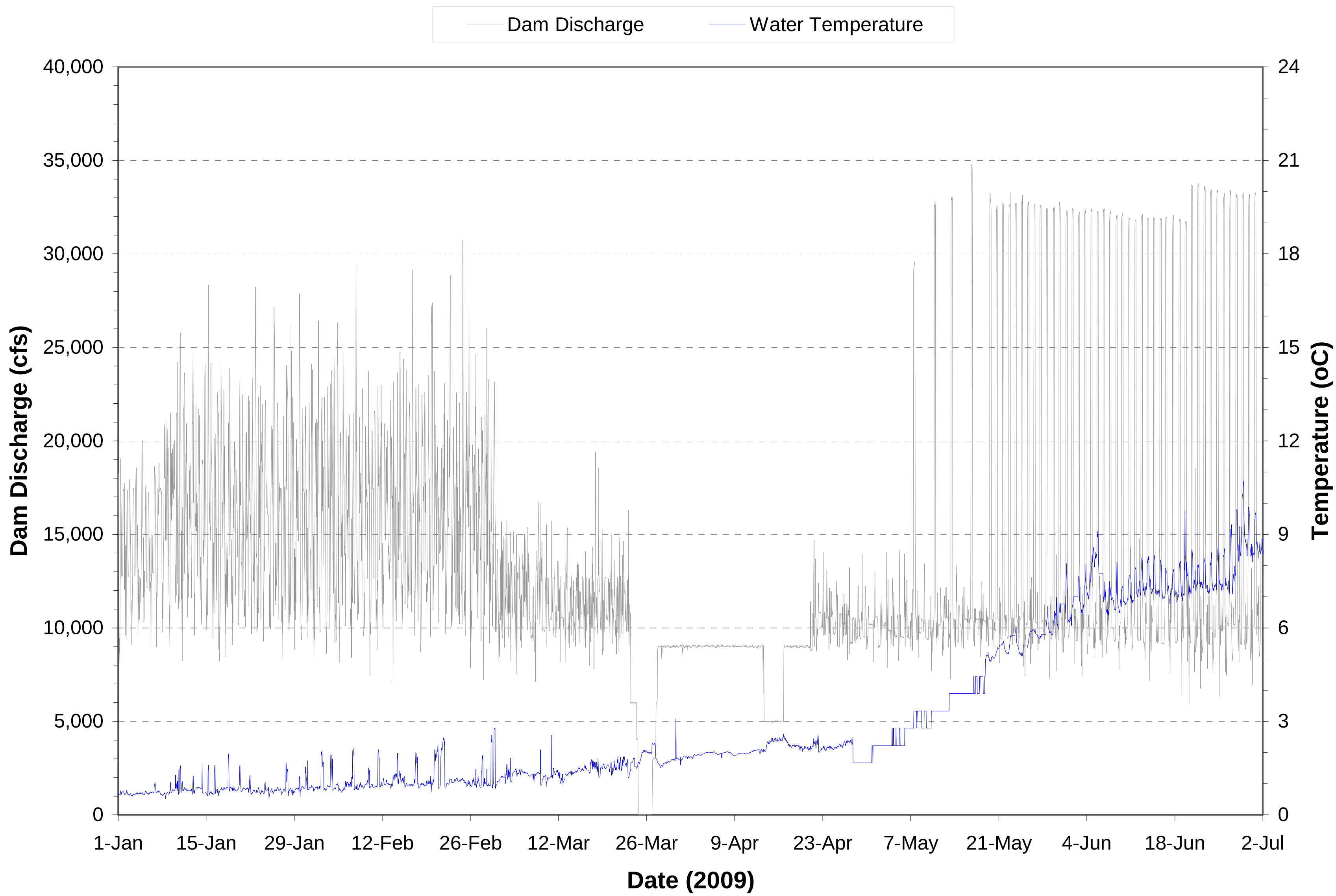


Plate 114. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2009.

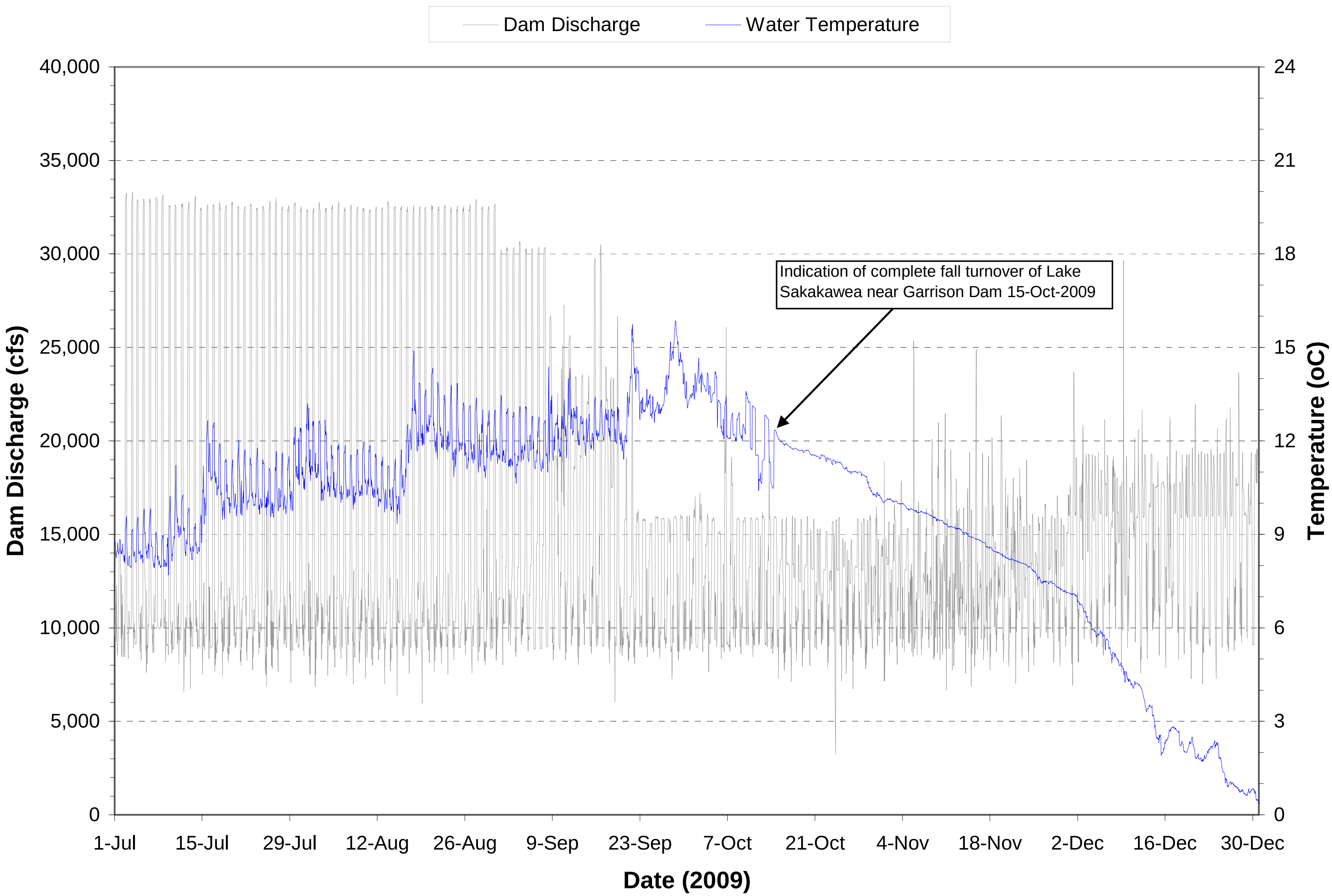


Plate 115. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2009.

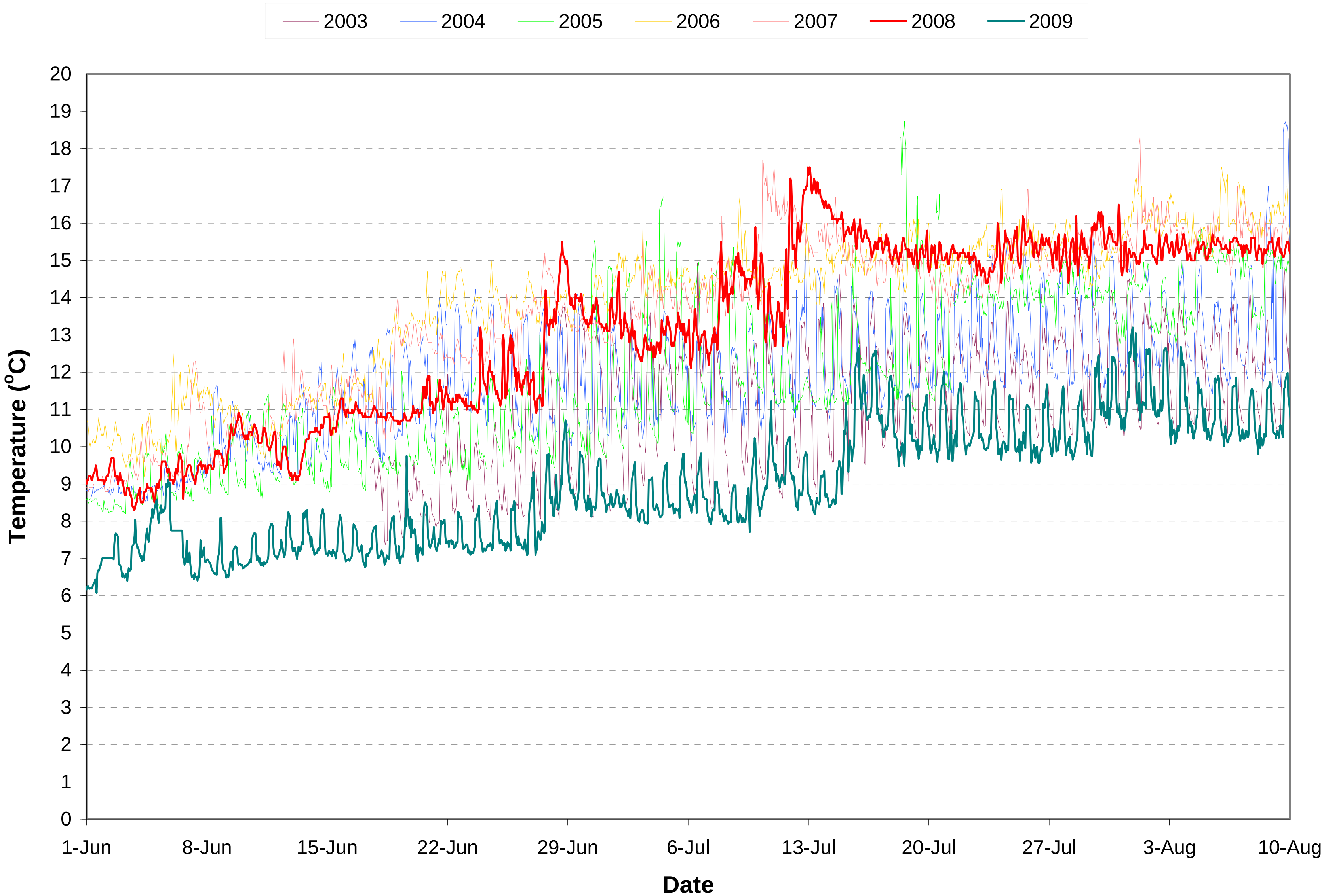


Plate 116. Hourly temperature of water discharged through Garrison Dam during the period June 1 through Mid-August in 2003, 2004, 2005, 2006, 2007, 2008, and 2009.

Plate 117. Hourly temperature of water discharged through Garrison Dam during the period Mid-August through October in 2003, 2004, 2005, 2006, 2007, 2008, and 2009.

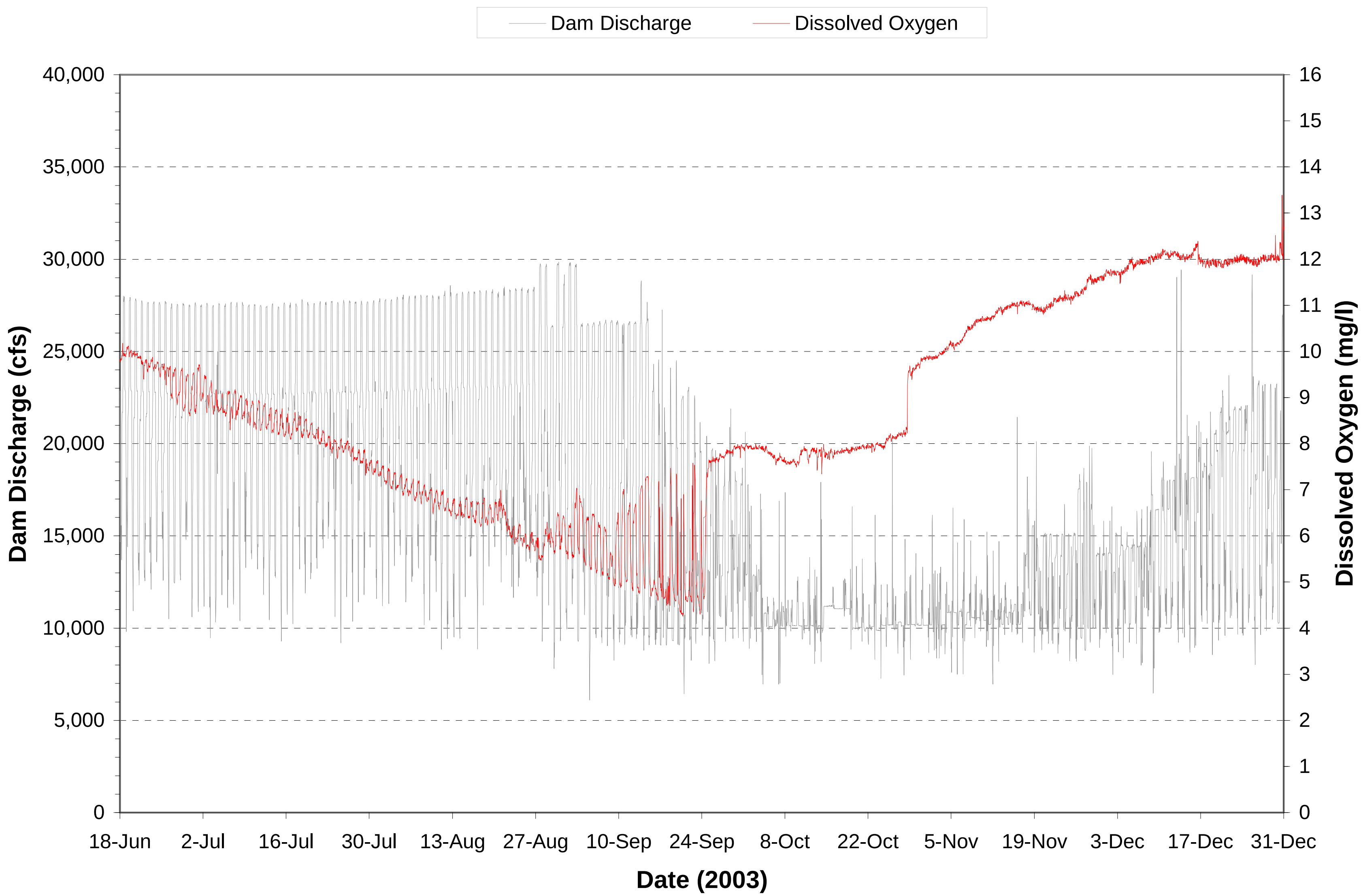


Plate 118. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period June through December 2003.

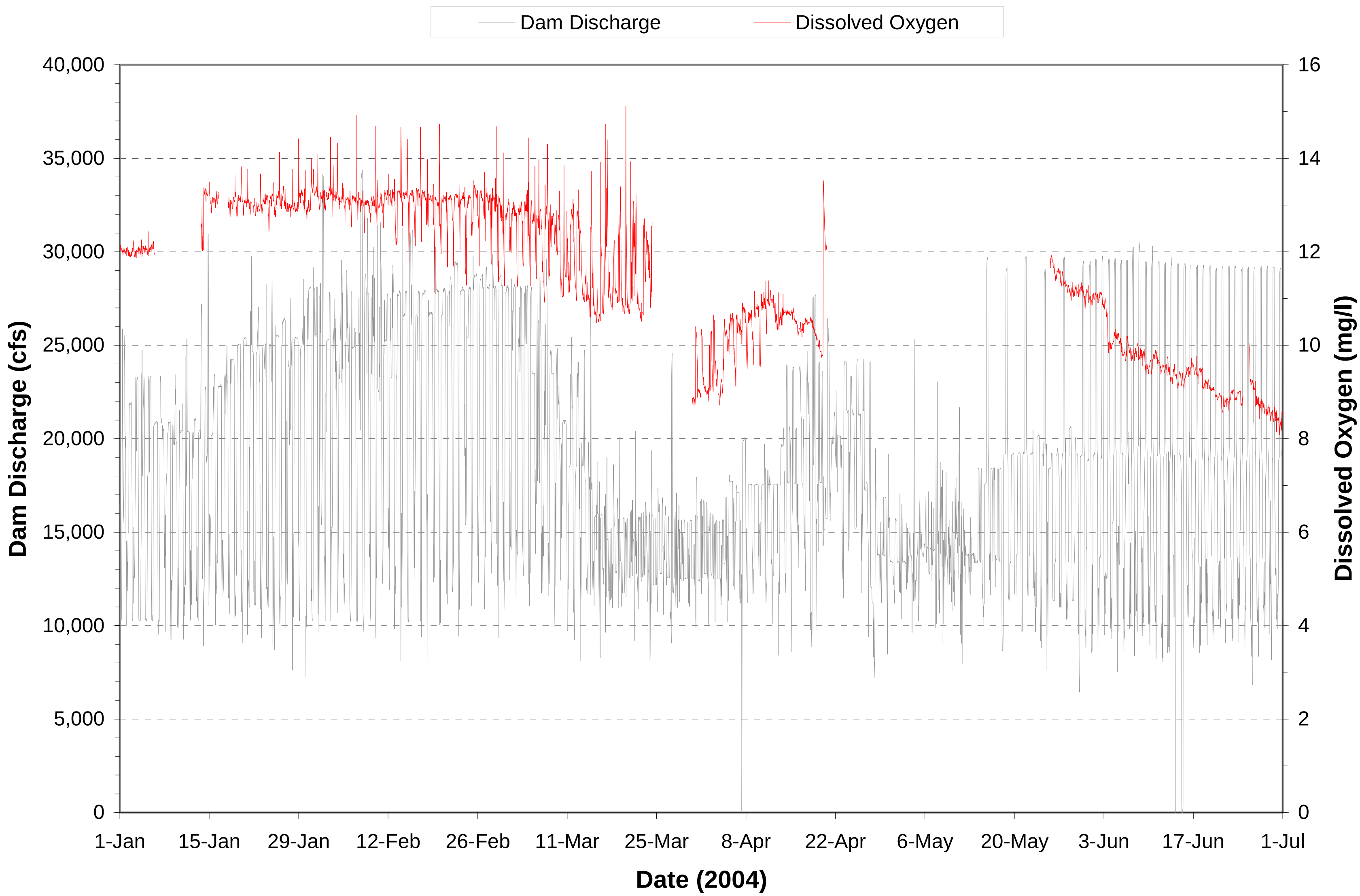


Plate 119. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2004.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

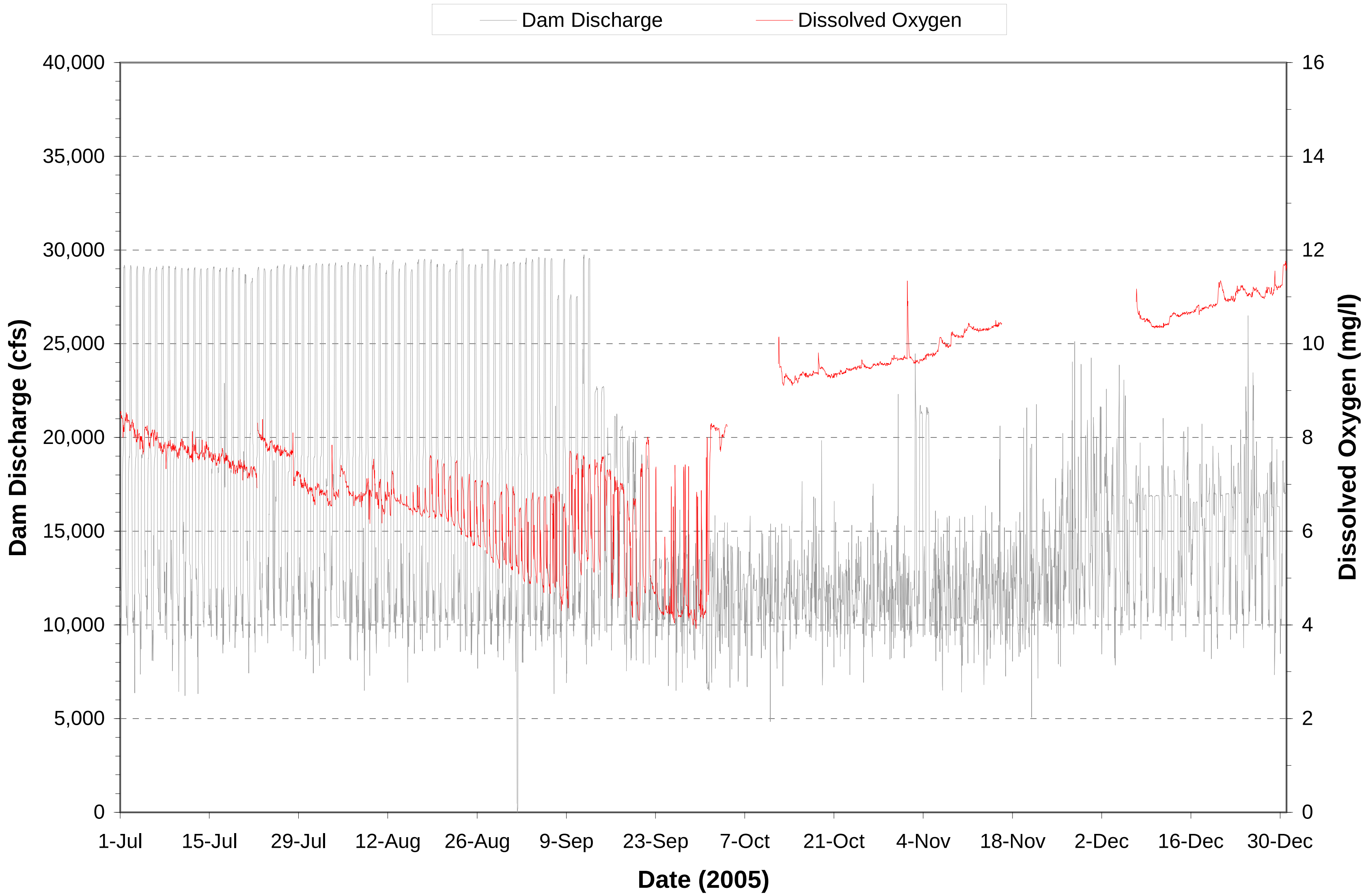


Plate 120. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2004.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

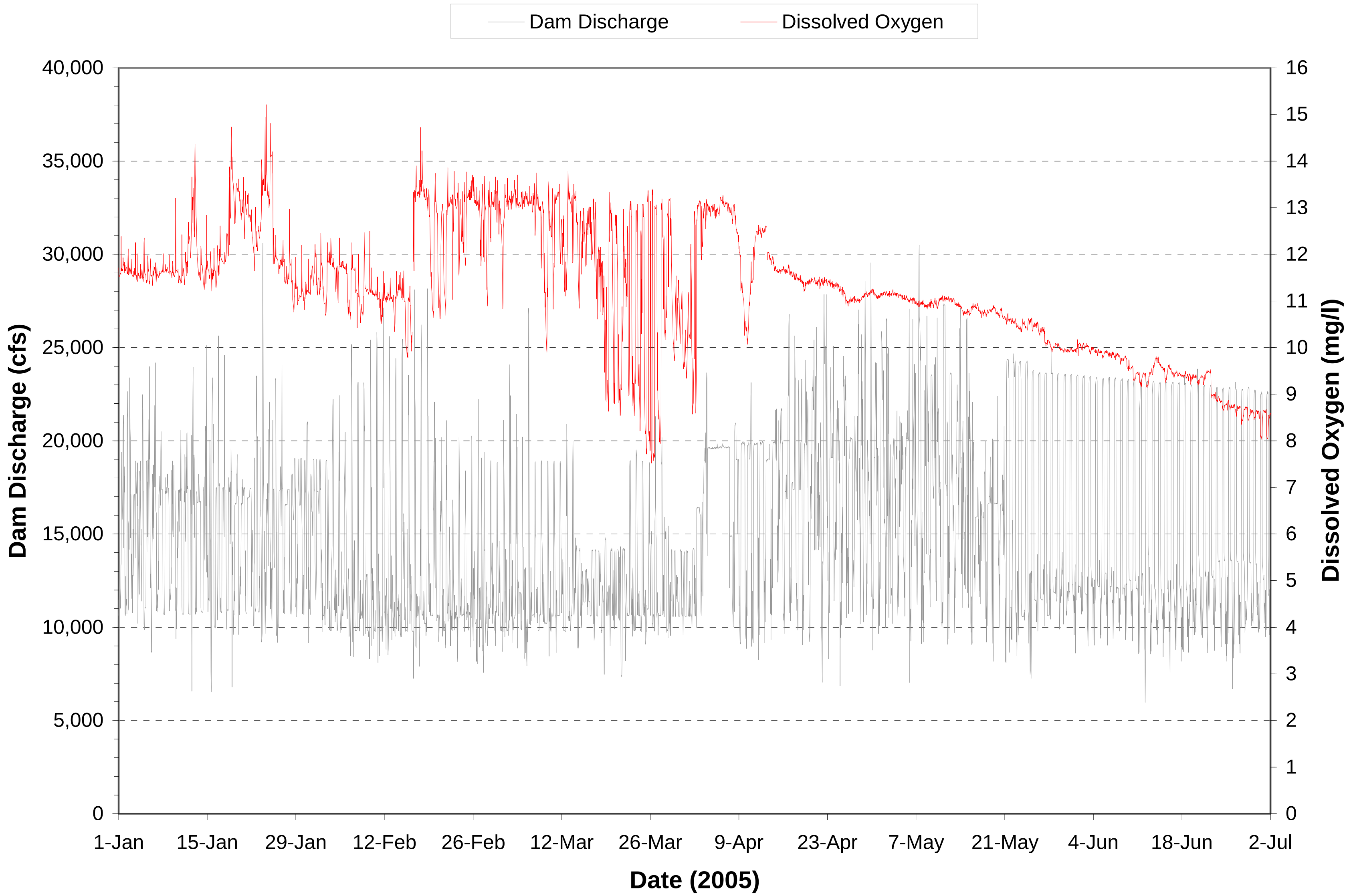


Plate 121. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2005.

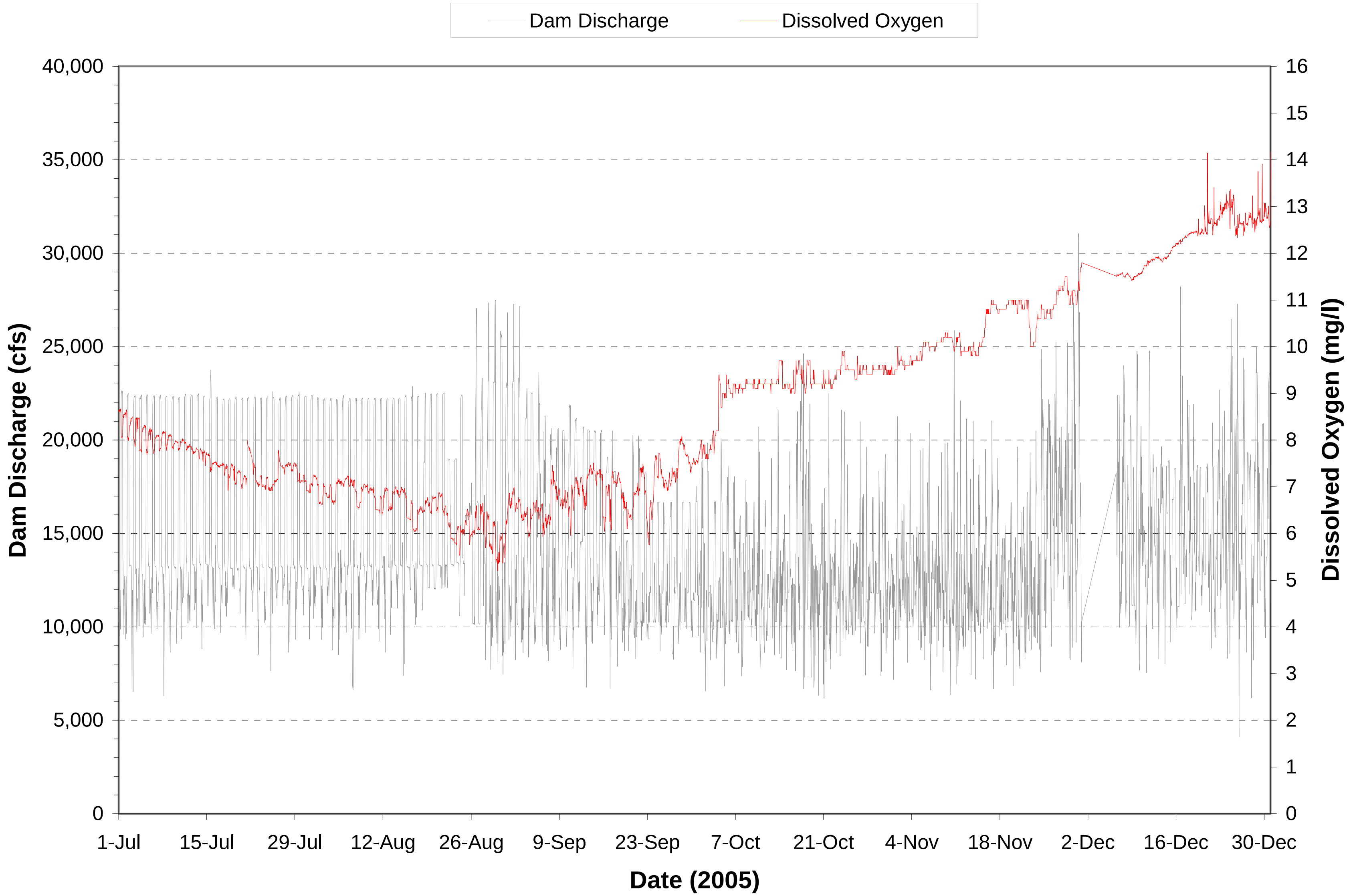


Plate 122. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2005.

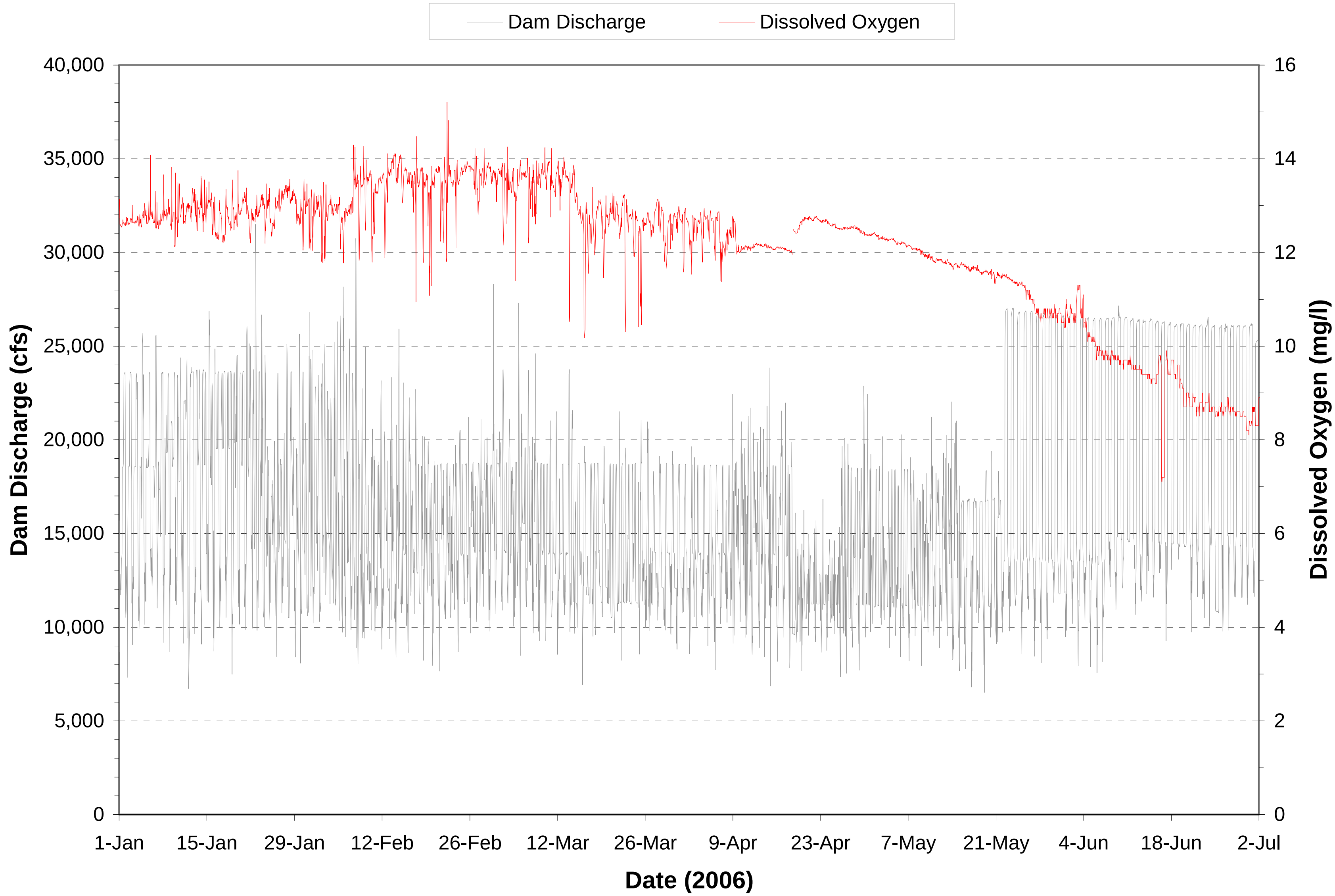


Plate 123. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2006.

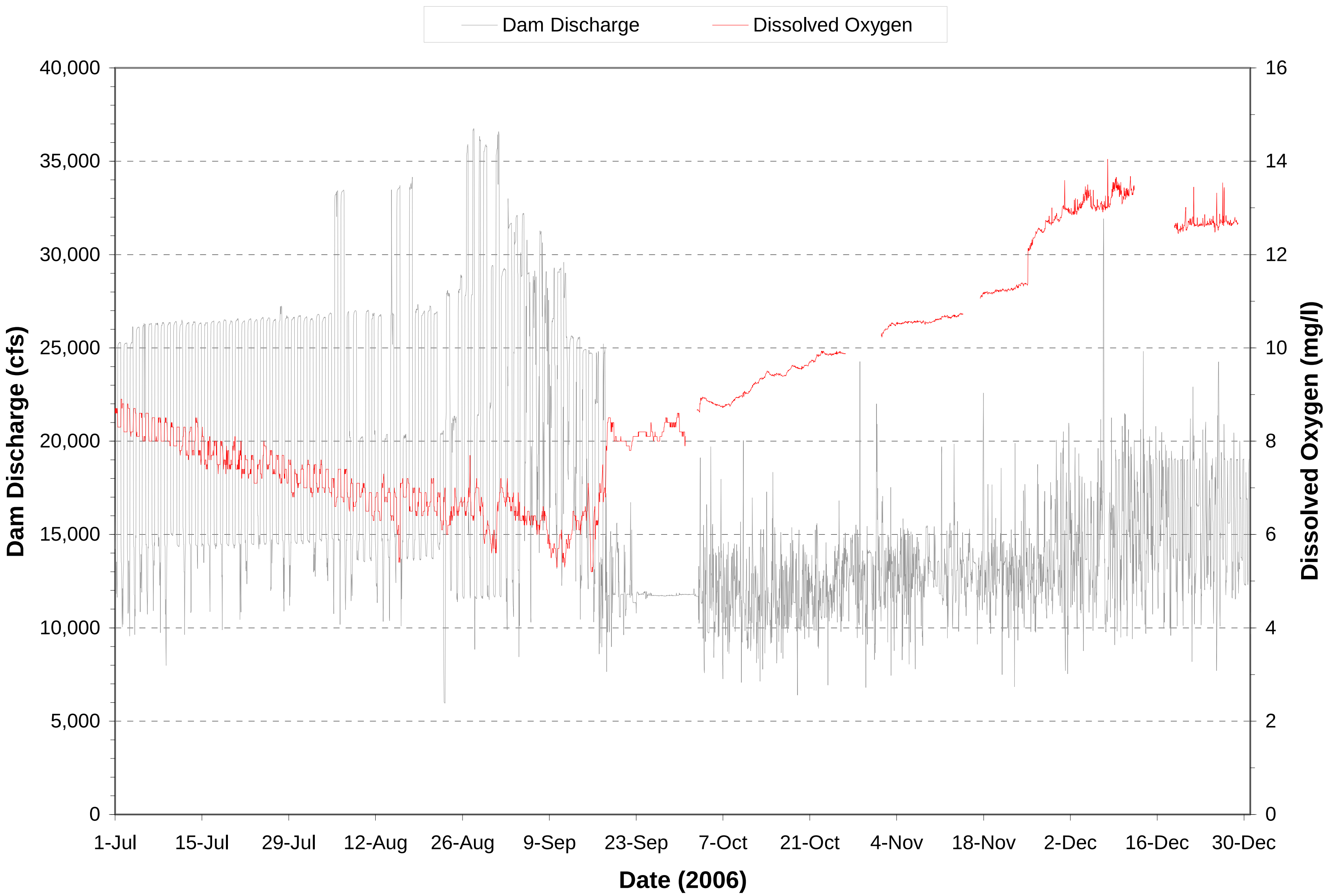


Plate 124. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2006.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

Plate 125. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2007.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

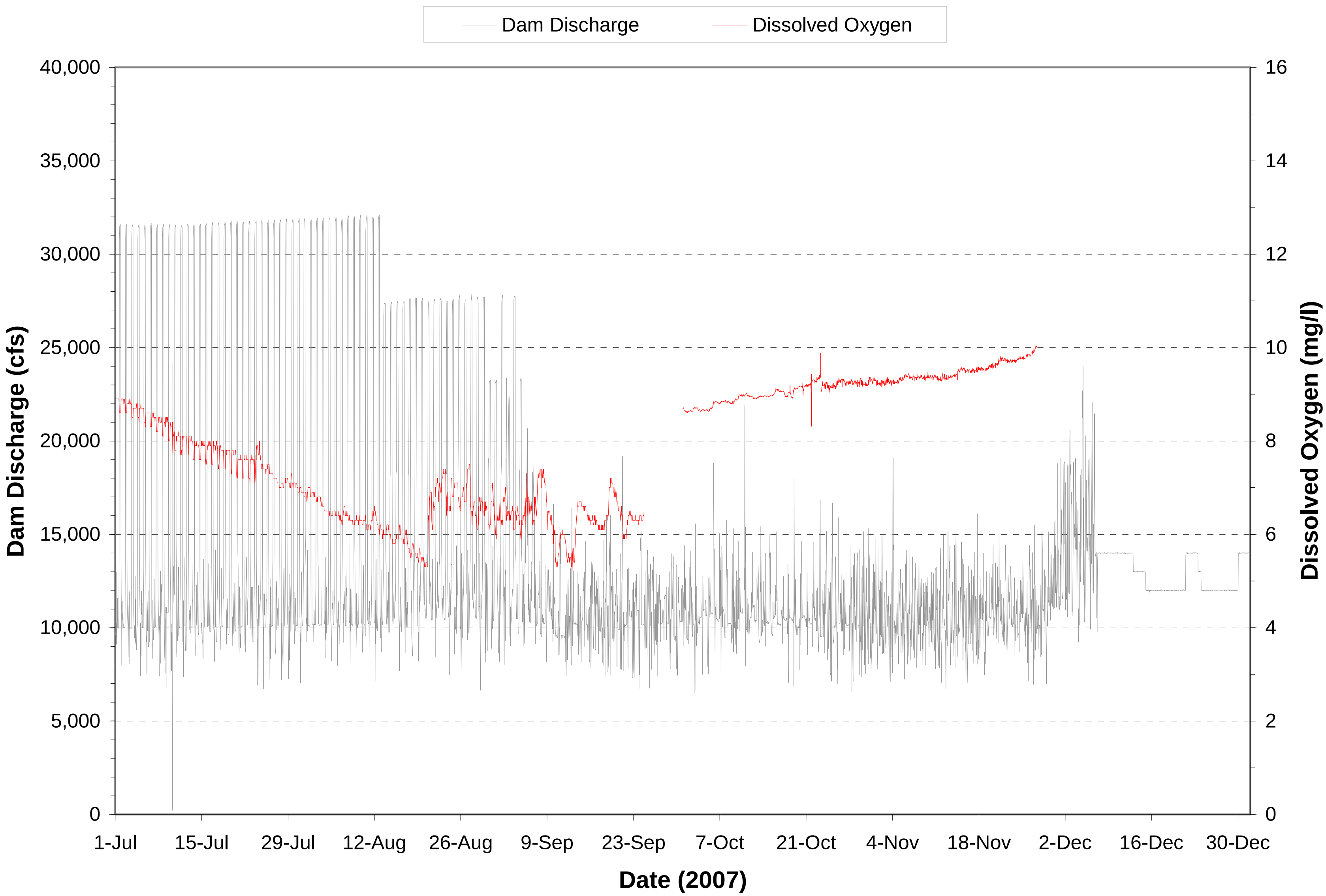


Plate 126. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

Plate 127. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2008.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

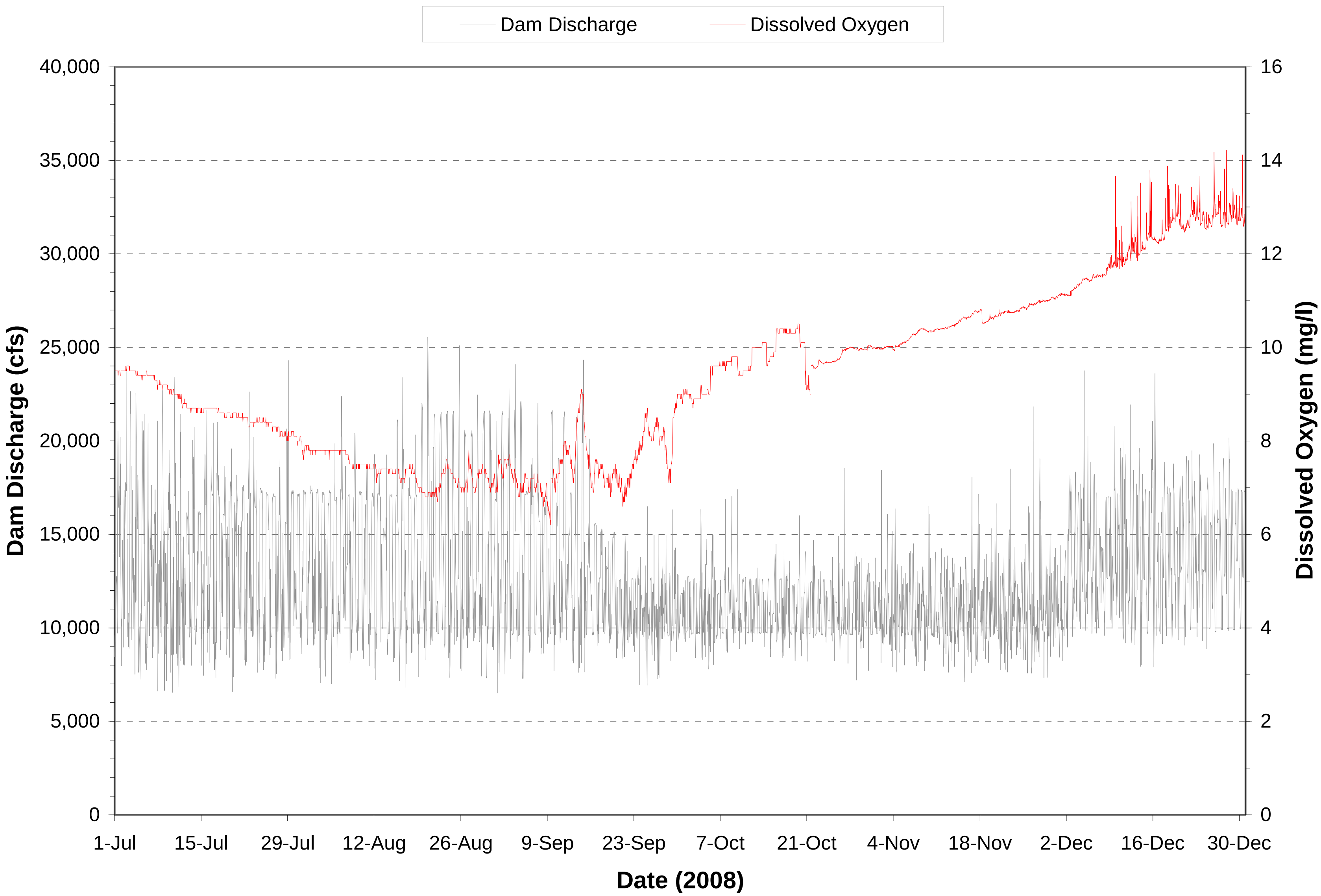


Plate 128. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2008.

Plate 129. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2009.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

Plate 130. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2009.

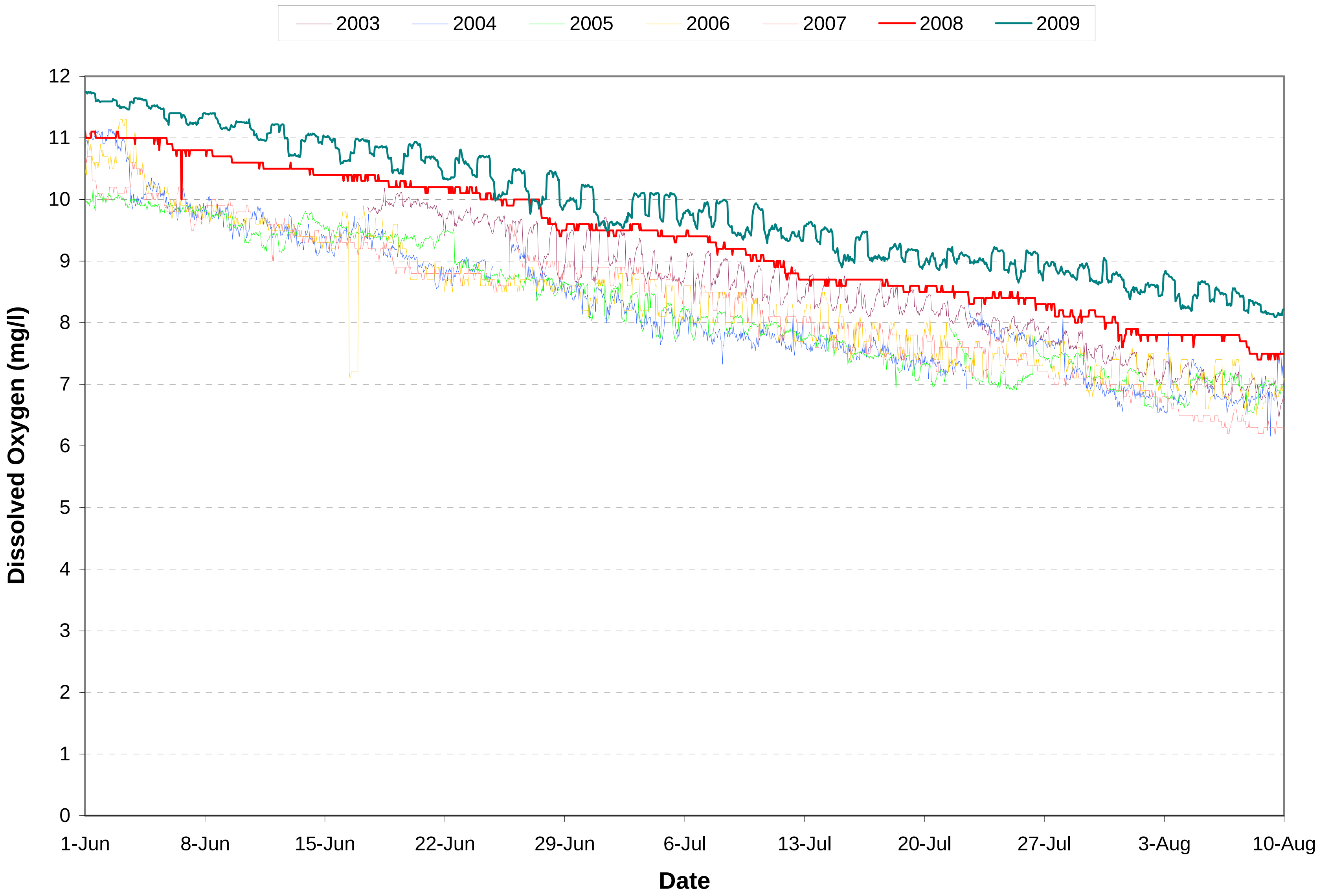


Plate 131. Hourly **d**issolved oxygen concentrations of water discharged through Garrison Dam during the period June through mid-August in 2003, 2004, 2005, 2006, 2007, 2008, and 2009.

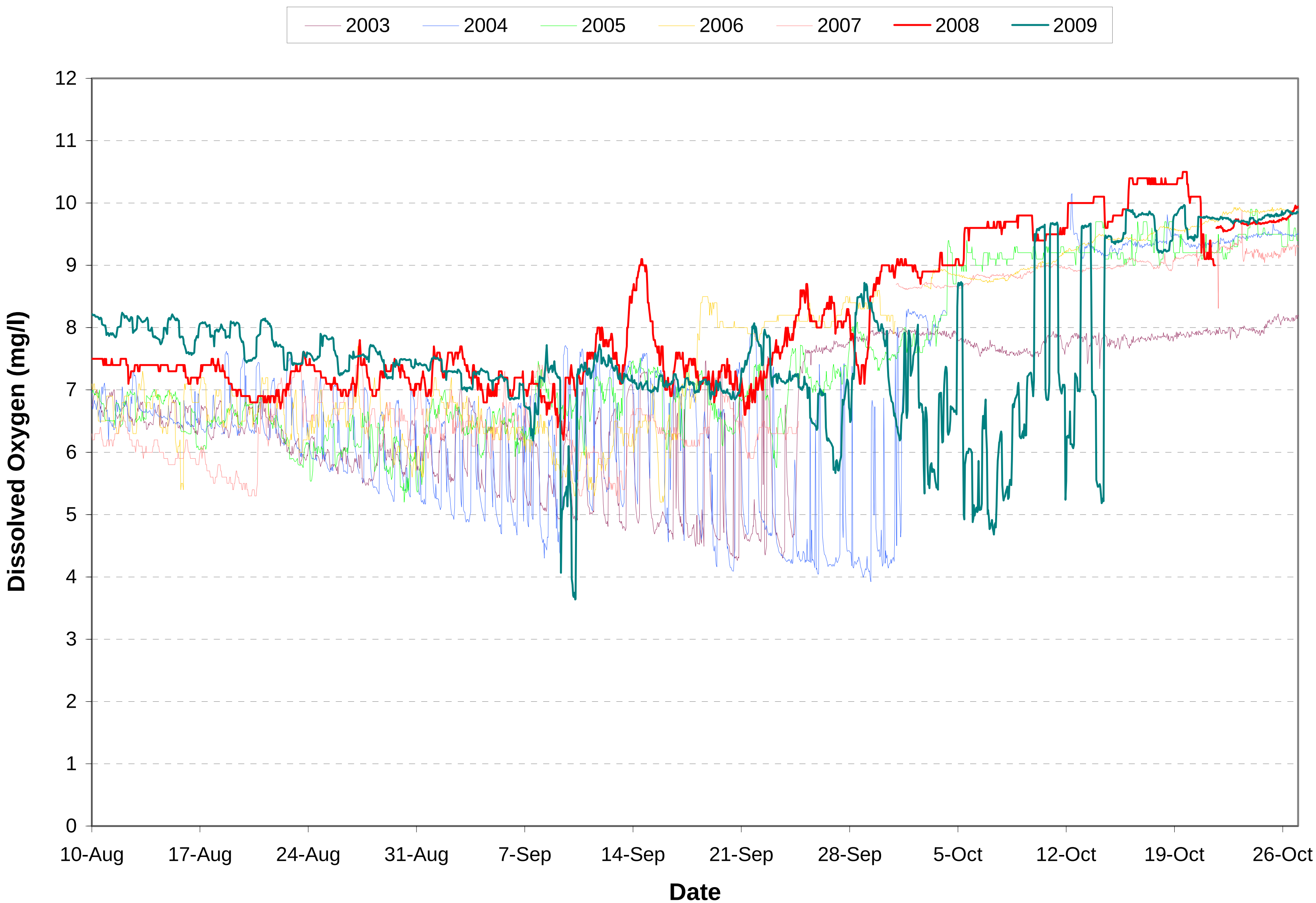


Plate 132. Hourly dissolved oxygen concentrations of water discharged through Garrison Dam during the period mid-August through October in 2003, 2004, 2005, 2006, 2007, 2008, 2009.

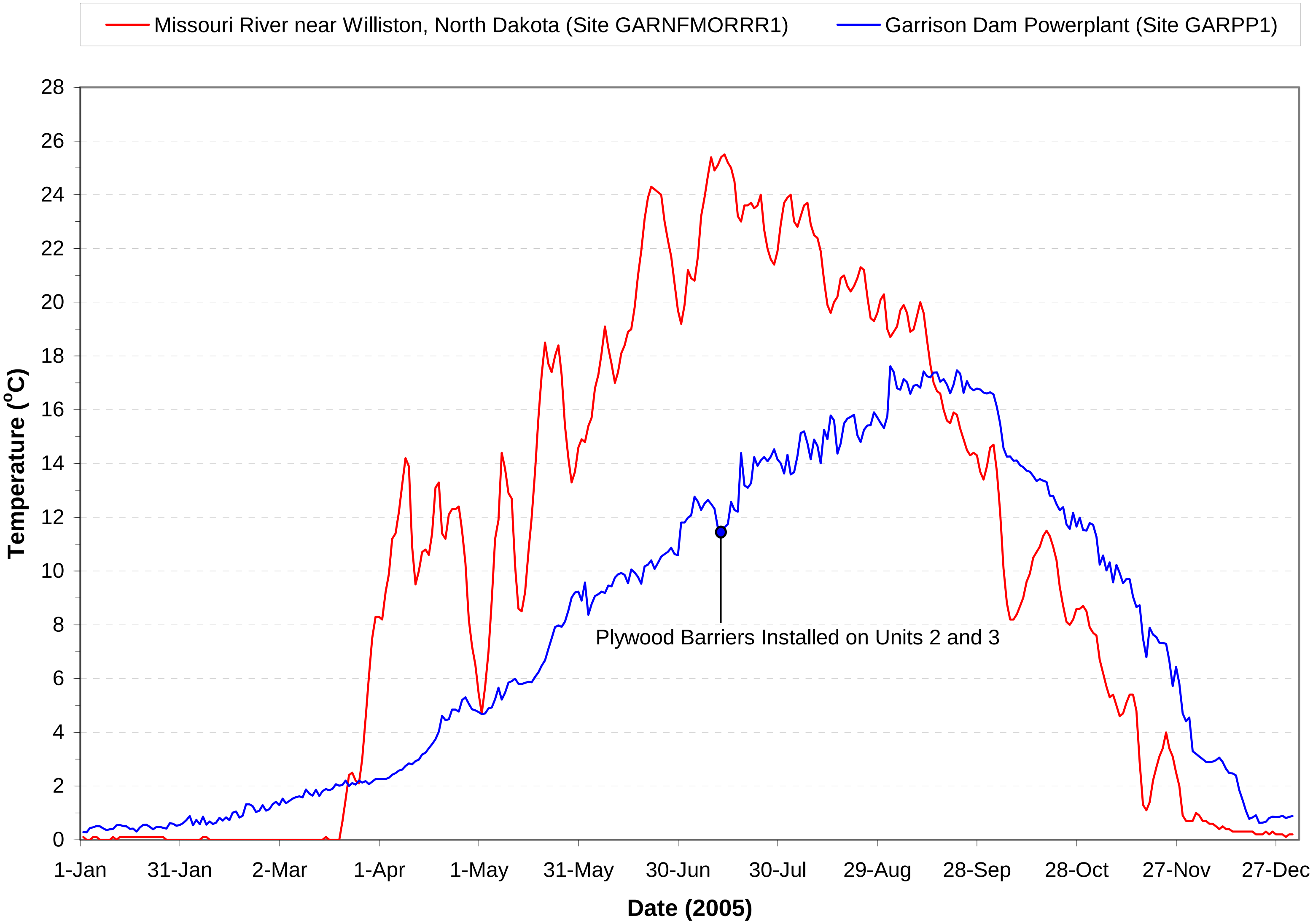


Plate 133. Mean daily water temperatures monitored at the Garrison Powerplant (i.e., site GARPP1) and the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) during 2005.

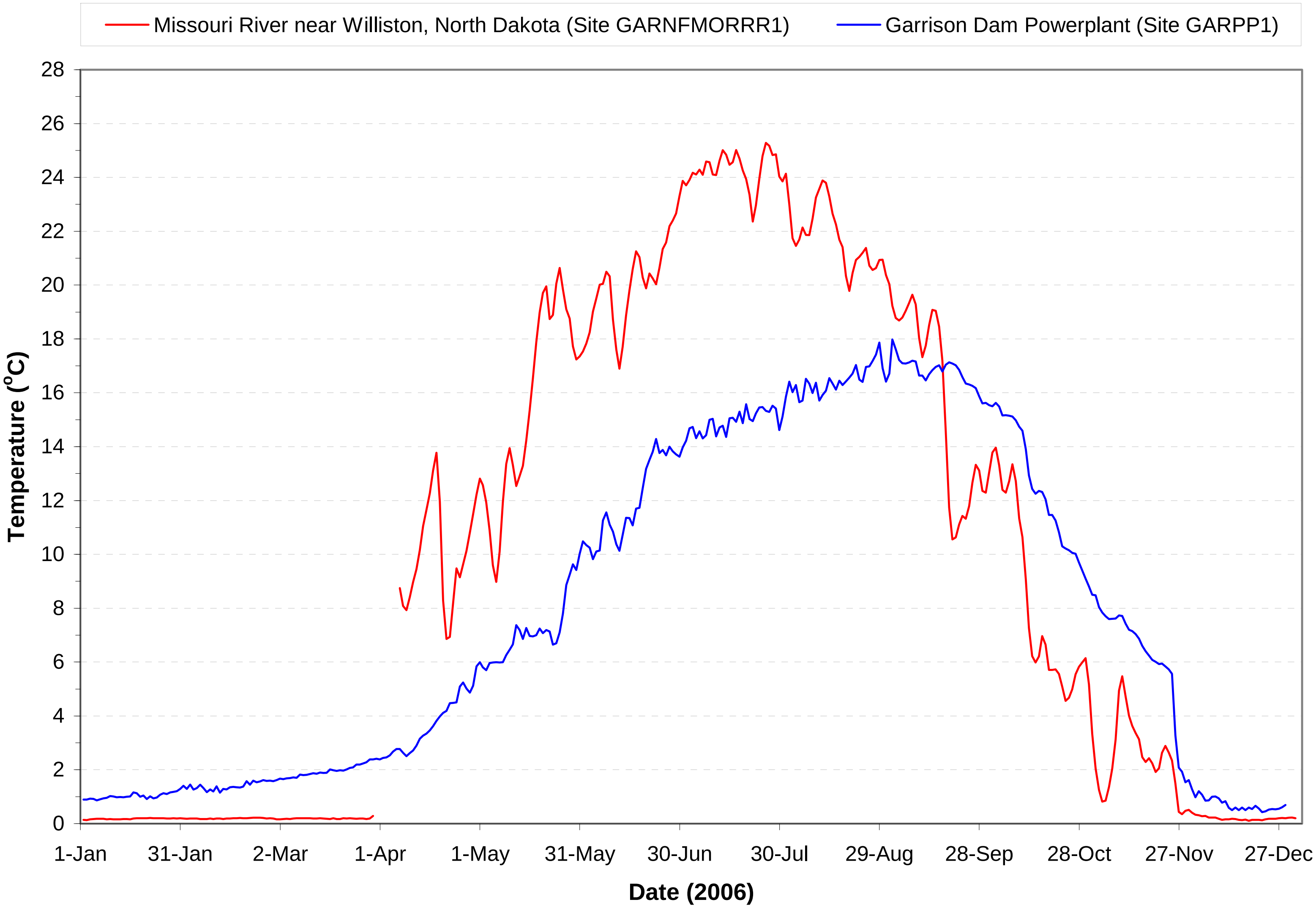


Plate 134. Mean daily water temperatures monitored at the Garrison Powerplant (i.e., site GARPP1) and the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) during 2006.

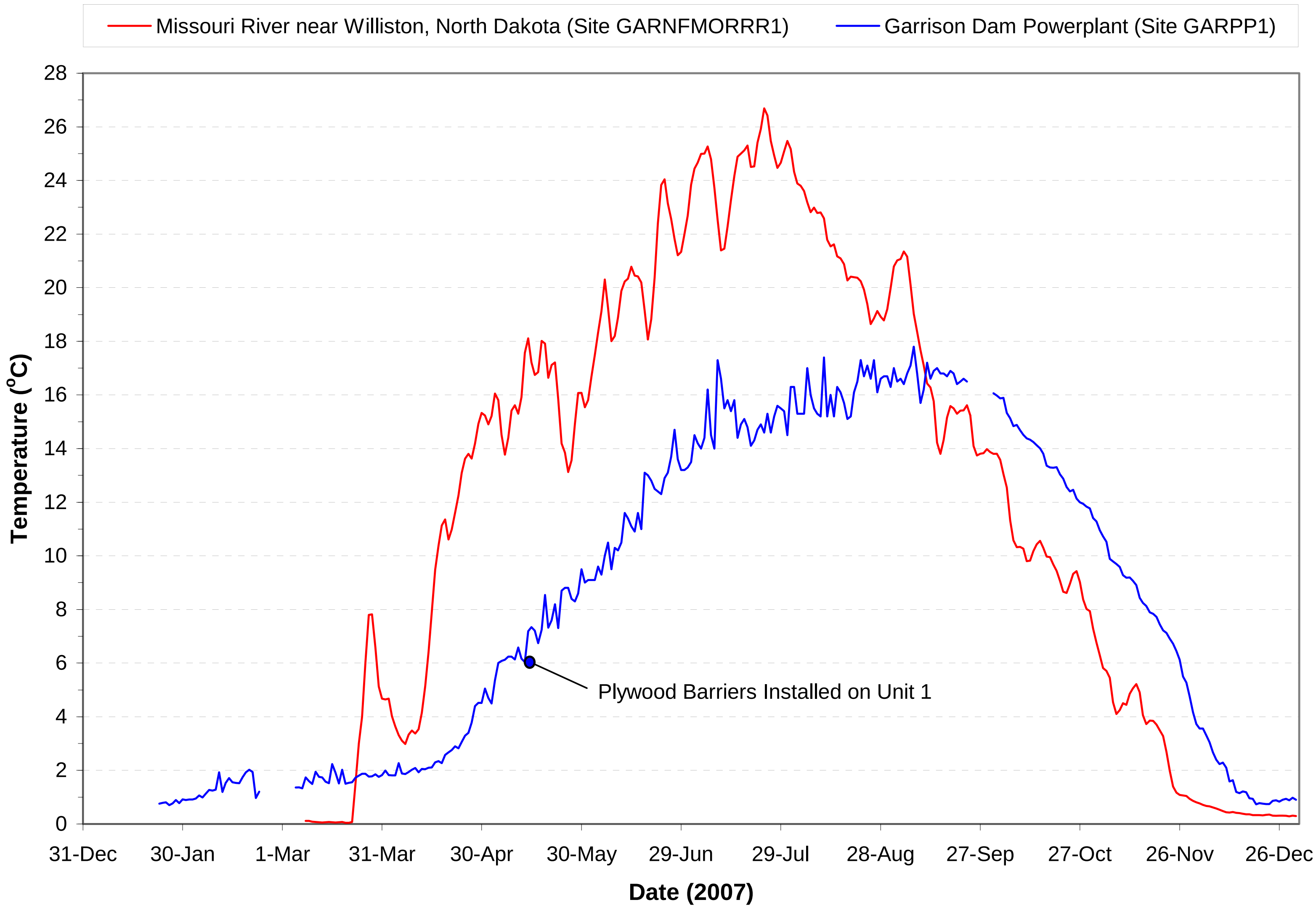


Plate 135. Mean daily water temperatures monitored at the Garrison Powerplant (i.e., site GARPP1) and the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) during 2007.

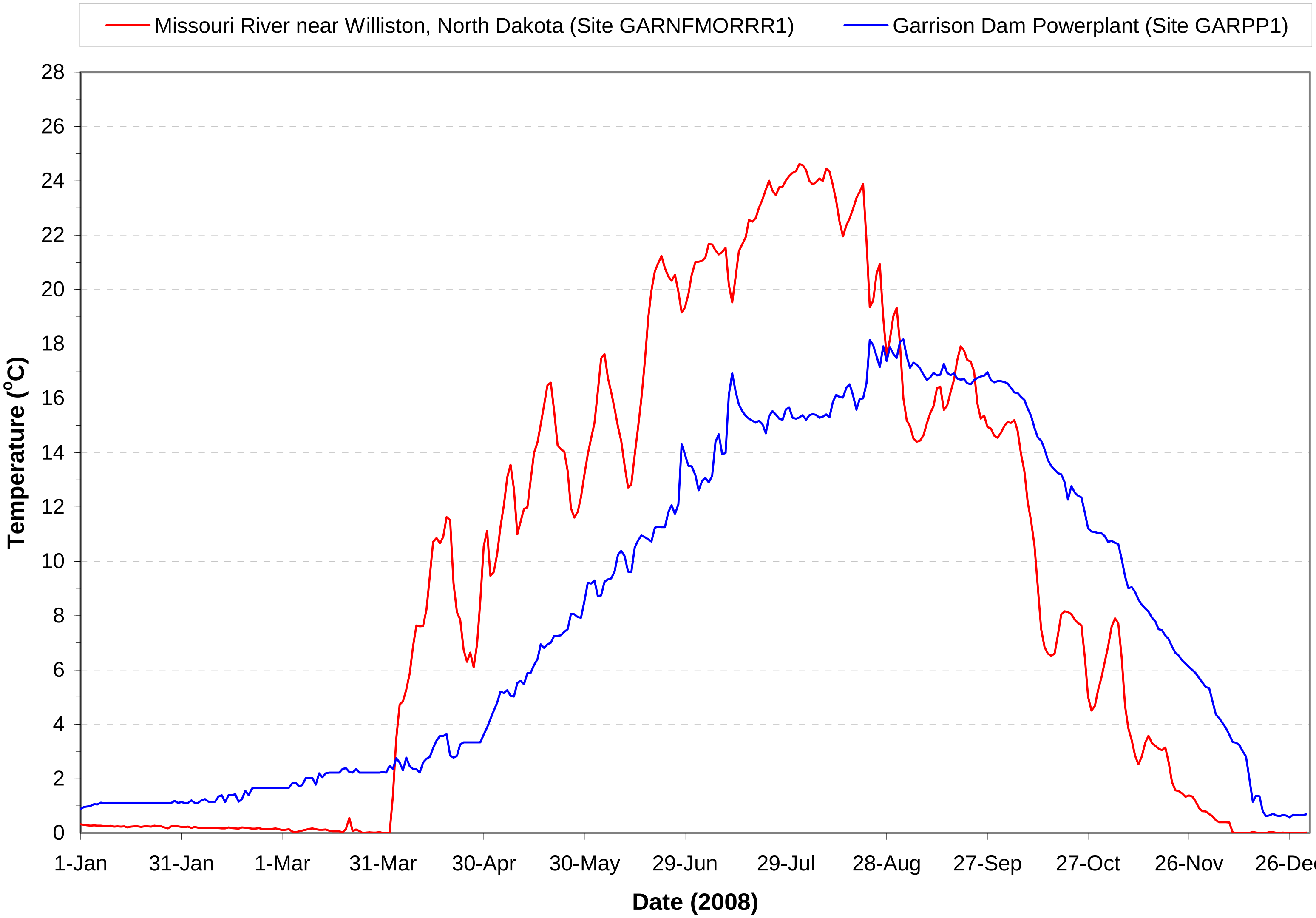


Plate 136. Mean daily water temperatures monitored at the Garrison Powerplant (i.e., site GARPP1) and the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) during 2008.

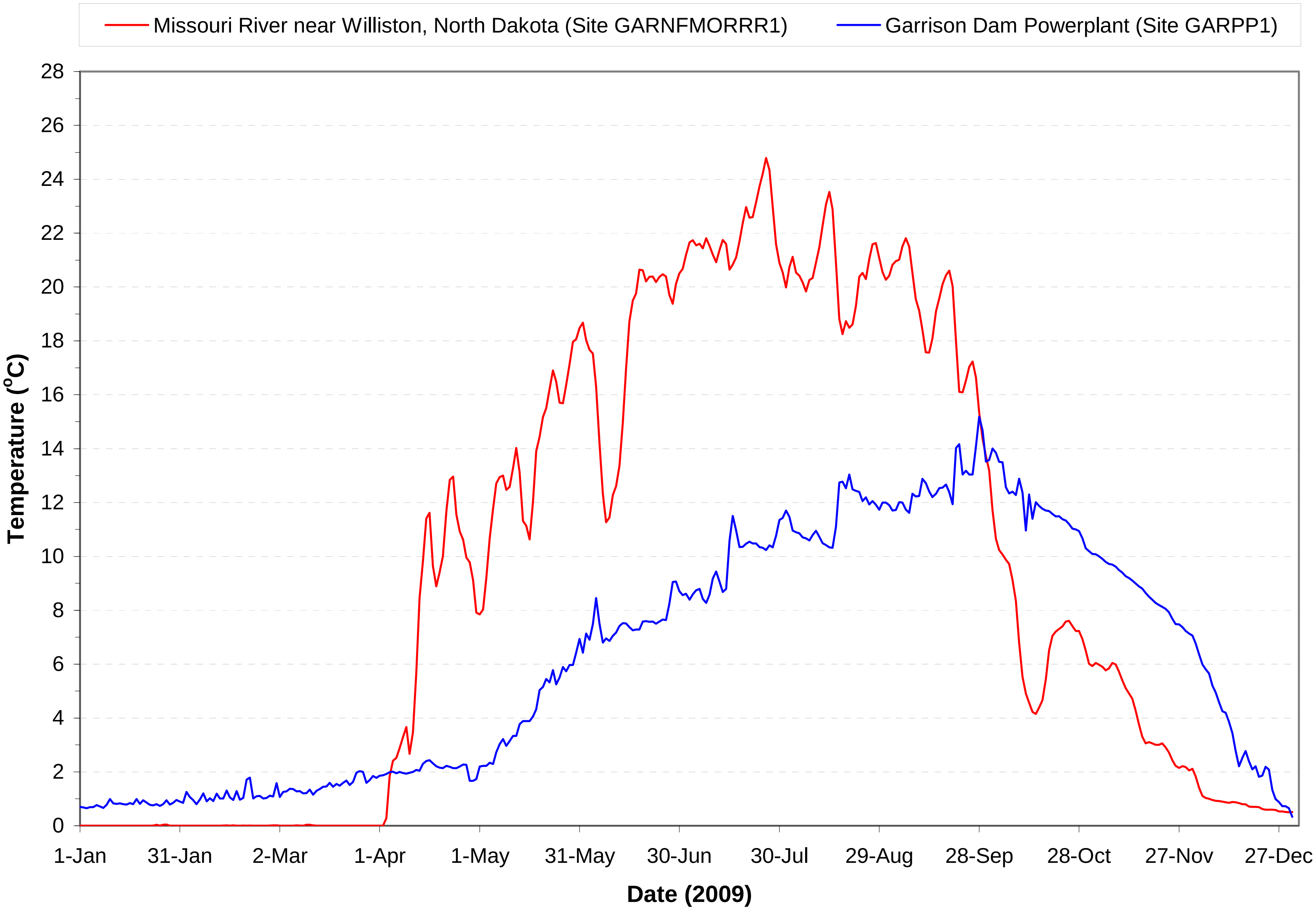


Plate 137. Mean daily water temperatures monitored at the Garrison Powerplant (i.e., site GARPP1) and the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) during 2009.

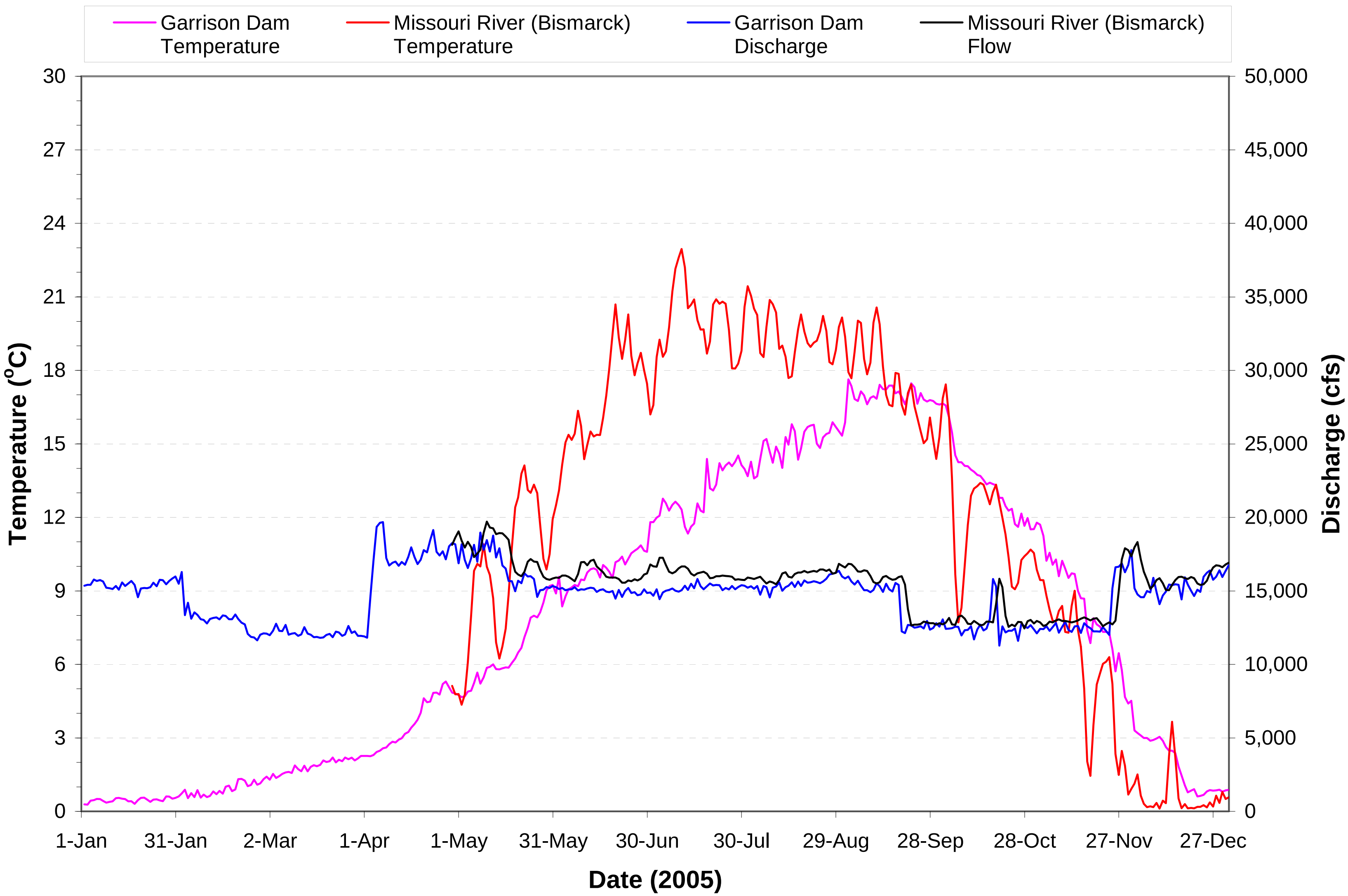


Plate 138. Mean daily water temperature and discharge for the Garrison Dam discharge and Missouri River at Bismarck, North Dakota for 2005. (Daily means based on hourly measurements.)

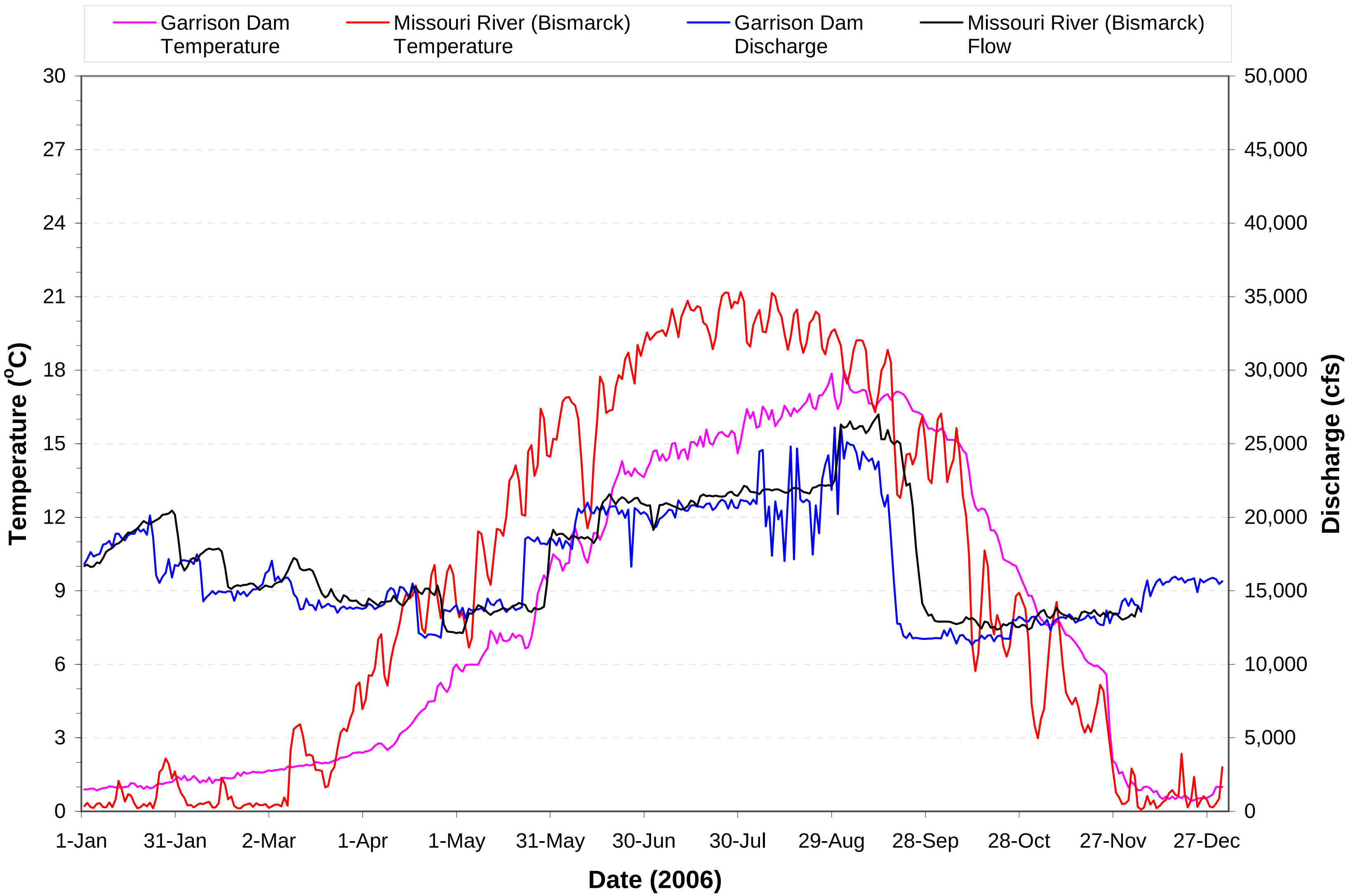


Plate 139. Mean daily water temperature and discharge for the Garrison Dam discharge and Missouri River at Bismarck, North Dakota for 2006. (Daily means based on hourly measurements.)

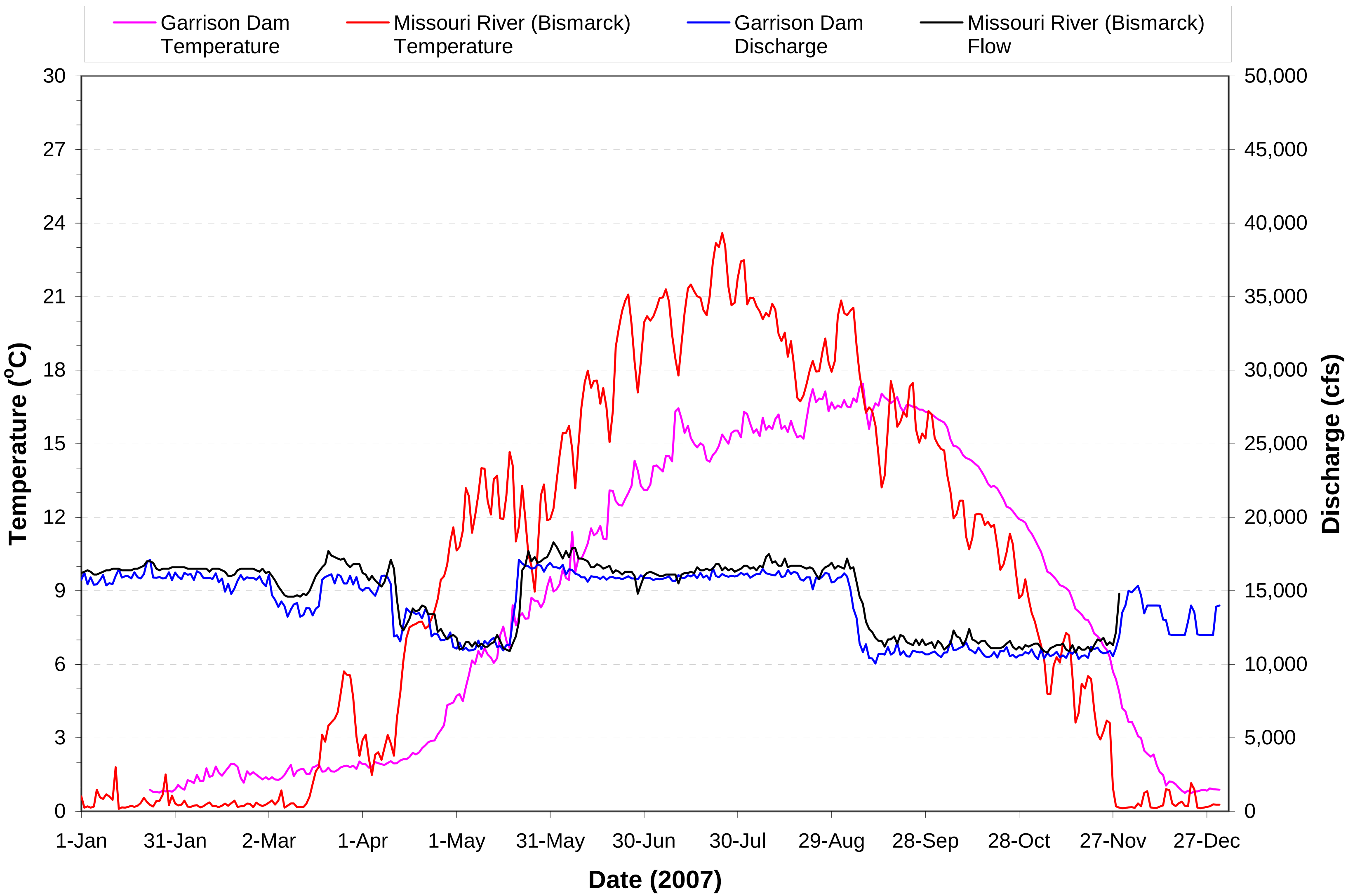


Plate 140. Mean daily water temperature and discharge for the Garrison Dam discharge and Missouri River at Bismarck, North Dakota for 2007. (Daily means based on hourly measurements.)

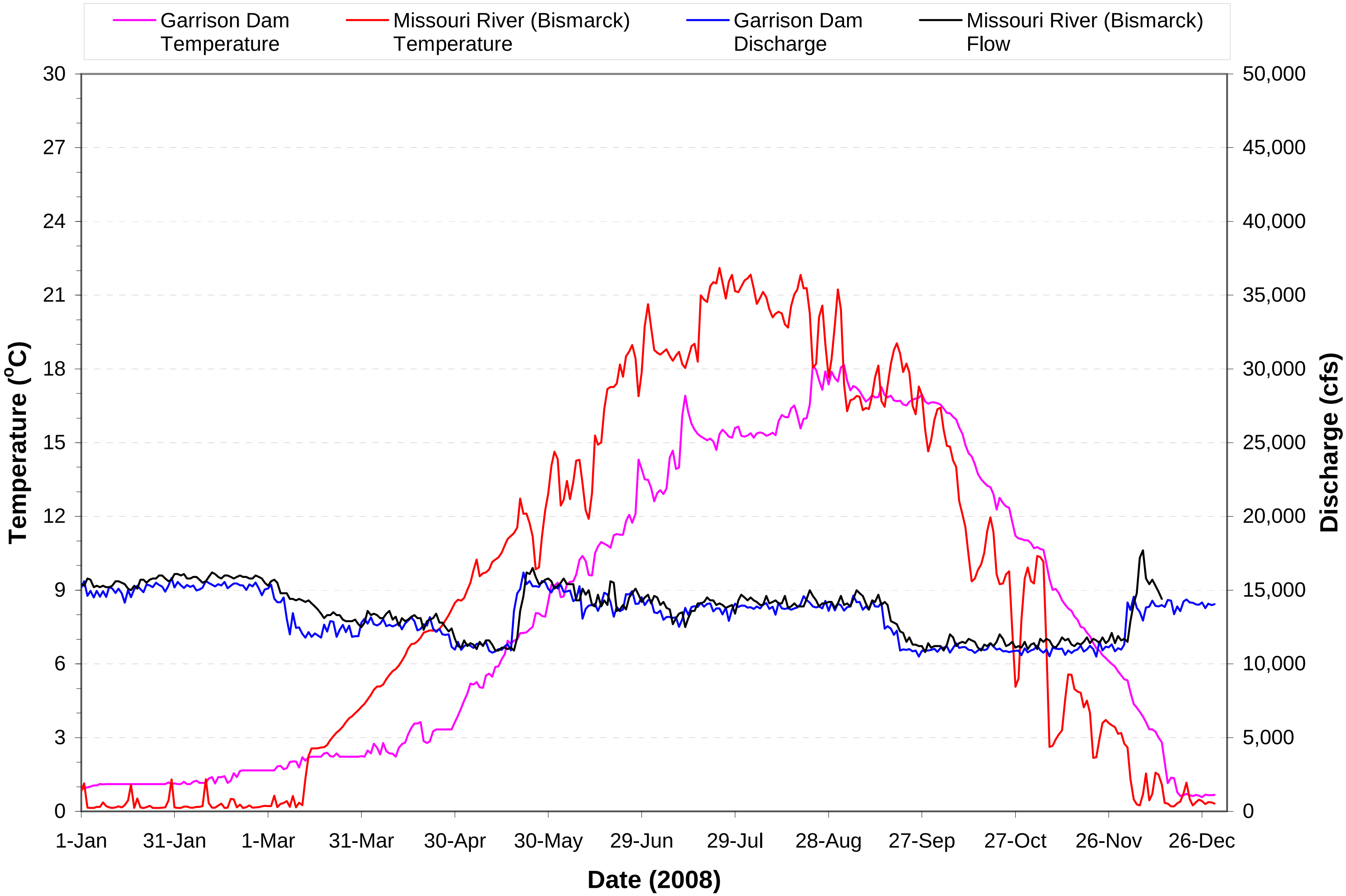


Plate 141. Mean daily water temperature and discharge for the Garrison Dam discharge and Missouri River at Bismarck, North Dakota for 2008. (Daily means based on hourly measurements.)

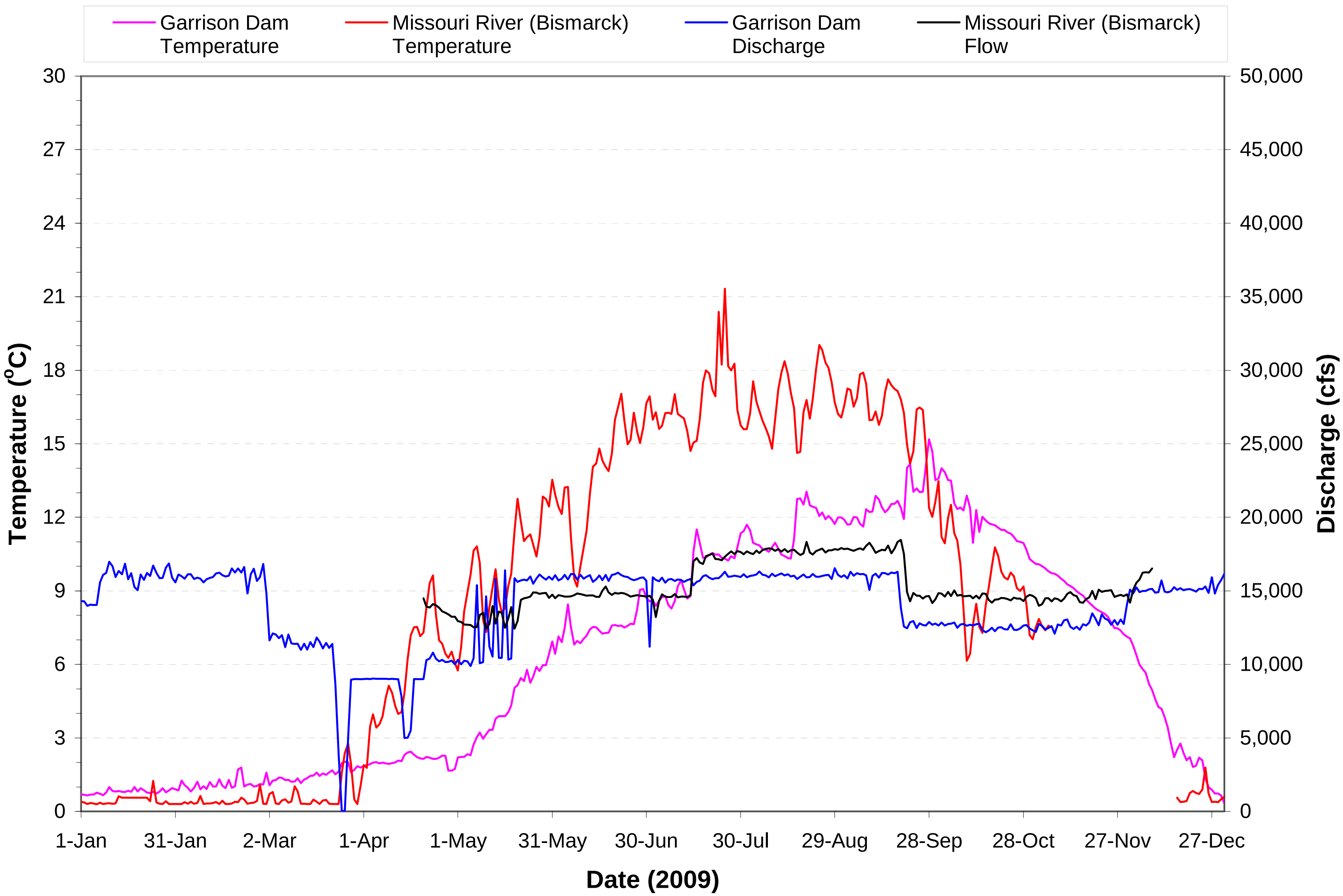


Plate 142. Mean daily water temperature and discharge for the Garrison Dam discharge and Missouri River at Bismarck, North Dakota for 2009. (Daily means based on hourly measurements.)

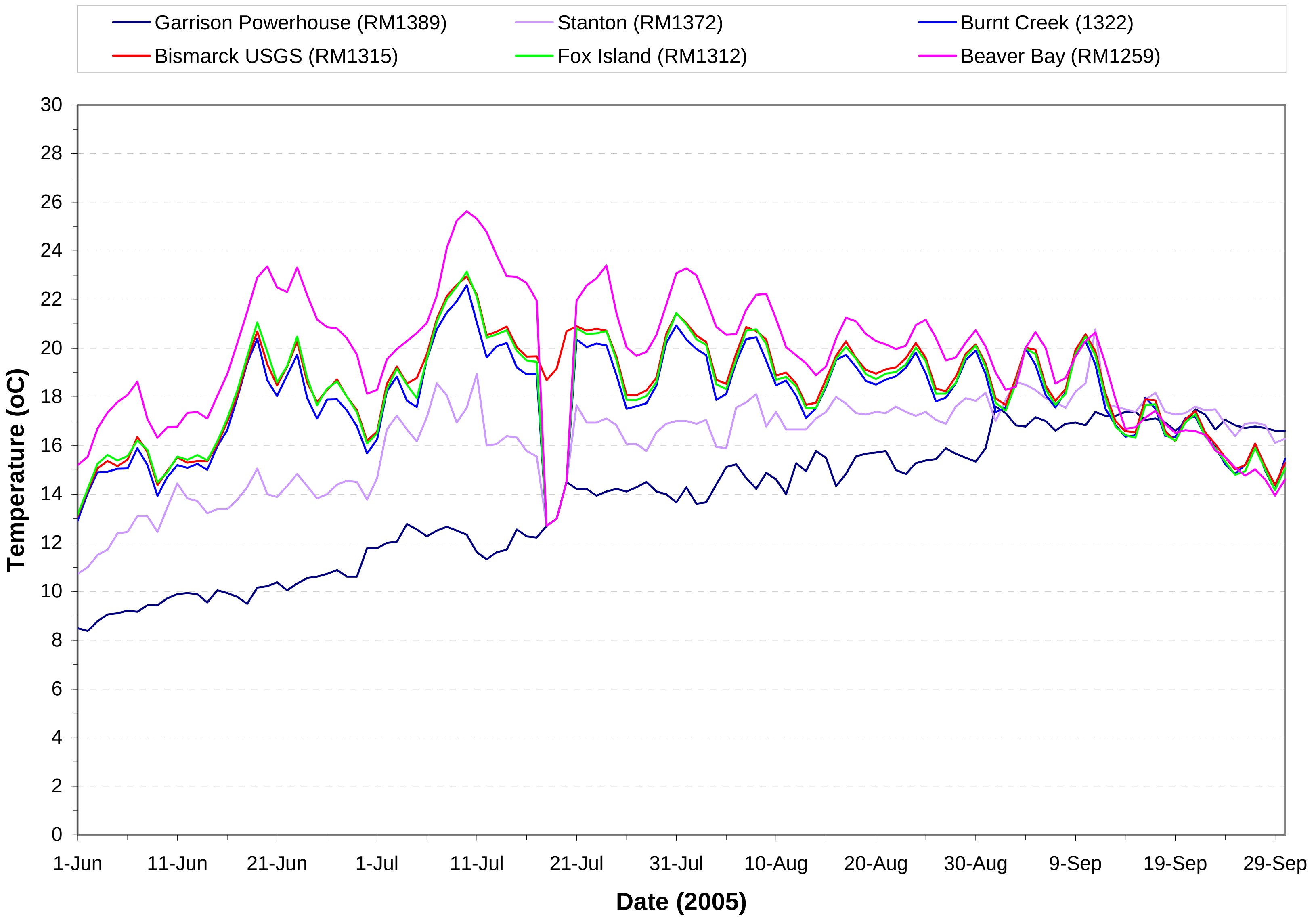


Plate 143. Mean daily water temperatures monitored in the Missouri River from Garrison Dam to Beaver Bay for the period June through September 2005.

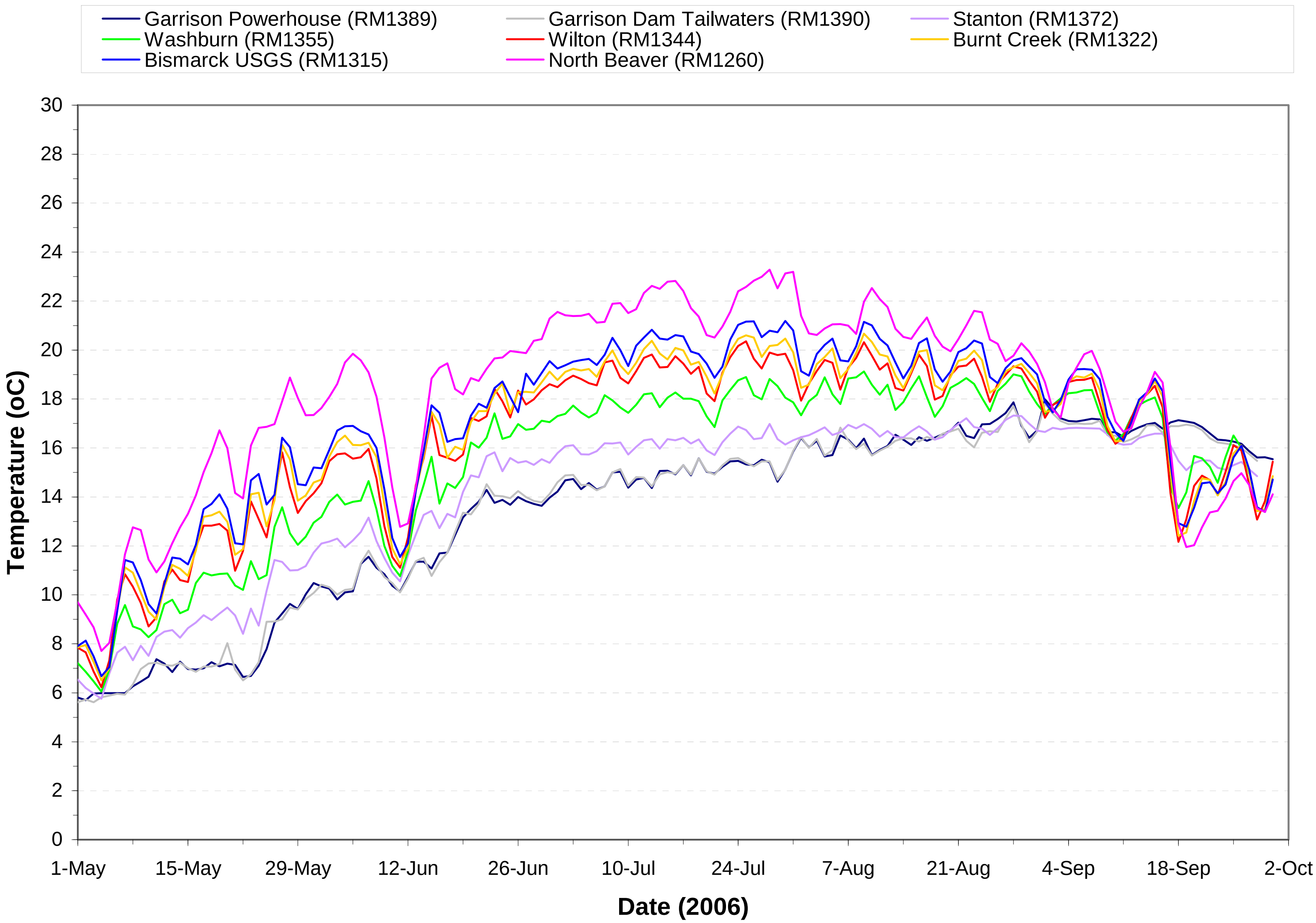


Plate 144. Mean daily water temperatures monitored in the Missouri River from Garrison Dam to Beaver Bay for the period May through September 2006.

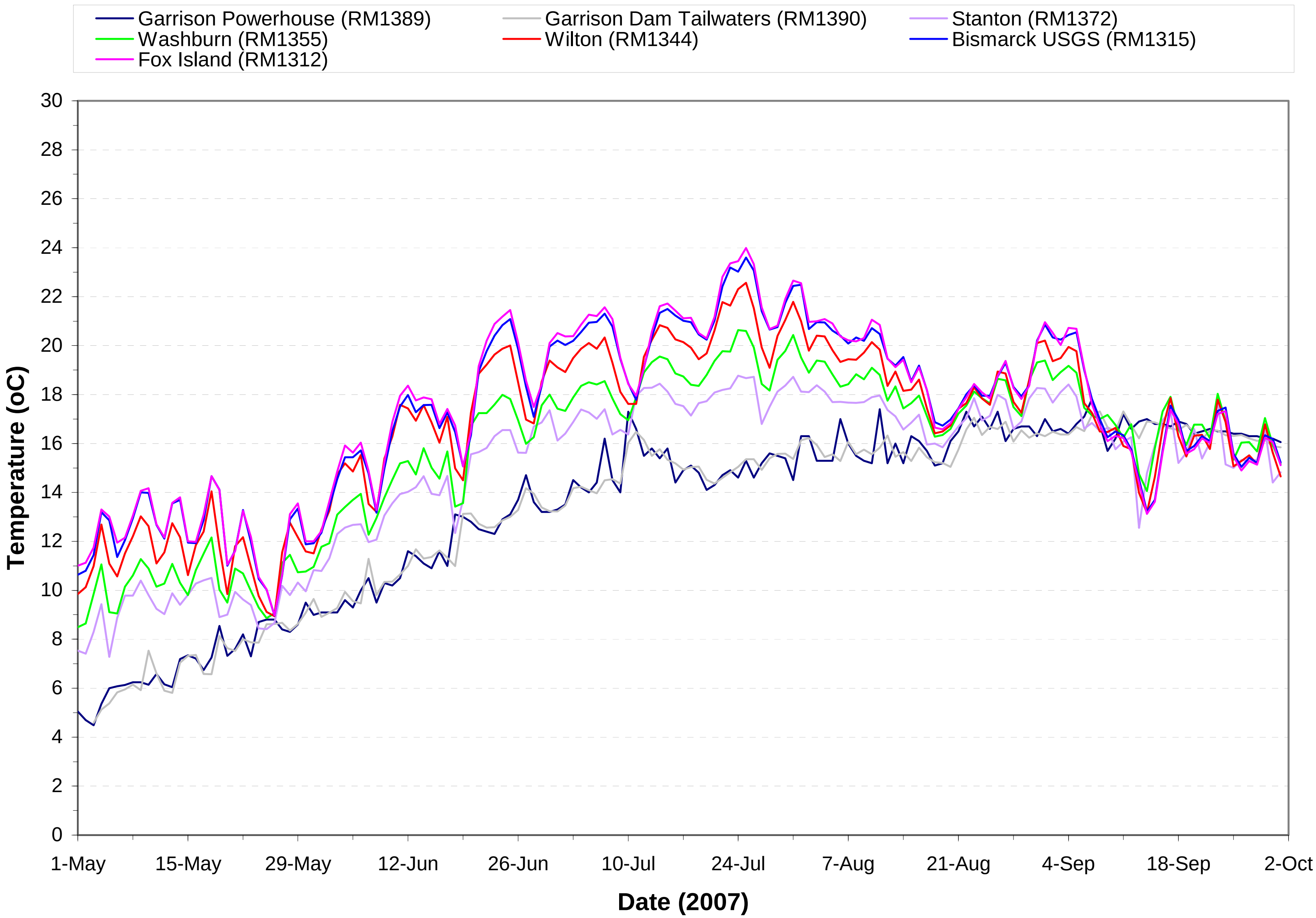


Plate 145. Mean daily water temperatures monitored in the Missouri River from Garrison Dam to Fox Island for the period May through September 2007.

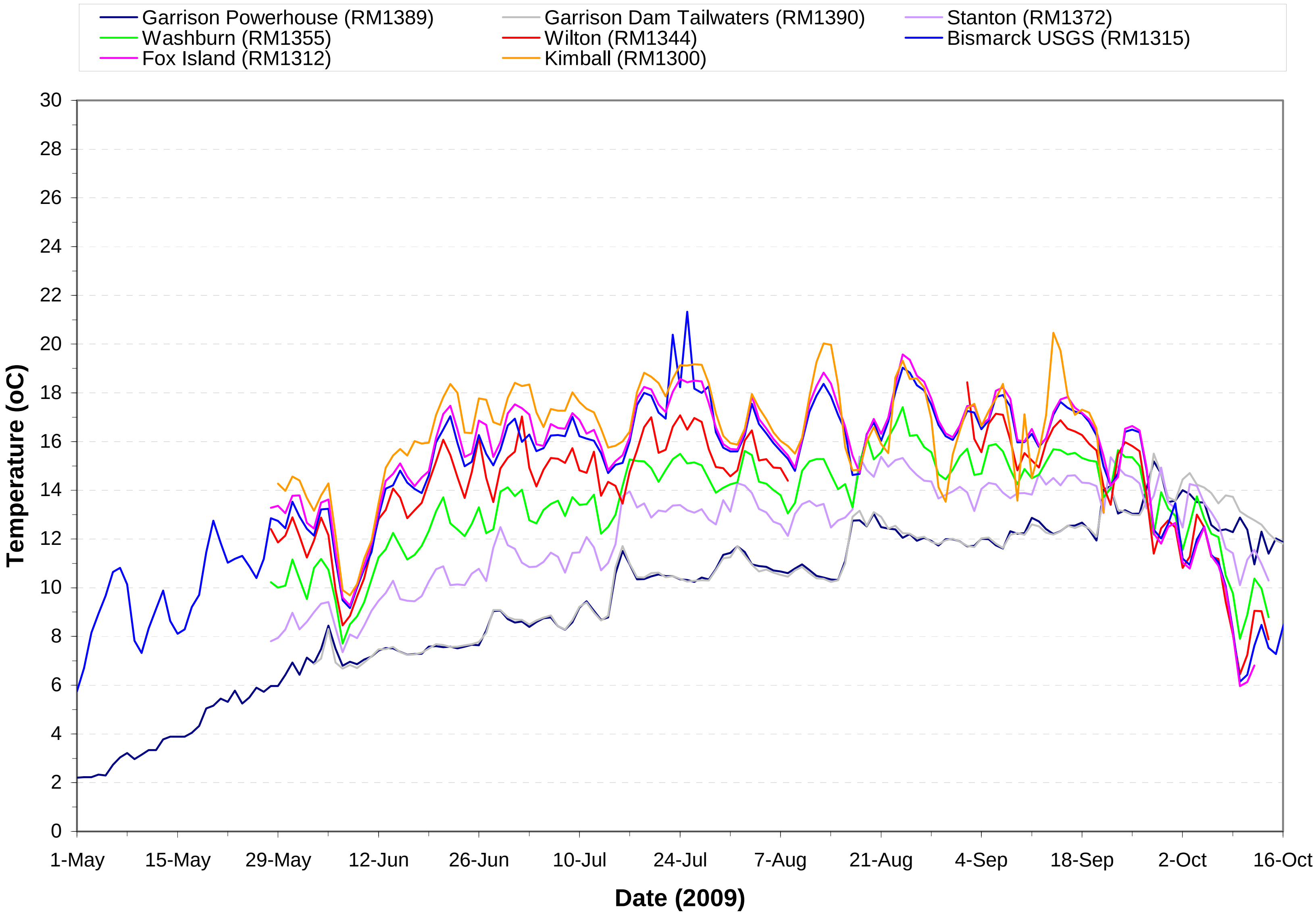


Plate 146. Mean daily water temperatures monitored in the Missouri River from Garrison Dam to Fox Island for the period May through mid-October 2009.

Plate 147. Summary of monthly (May through September) water quality conditions monitored in Lake Oahe near Oahe Dam (Site OAHLK1073A) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	25	1586.8	1580.6	1570.9	1613.5	-----	-----	-----
Water Temperature (°C)	0.1	1,162	12.8	11.1	5.1	24.9	18.3[1,5]	234	20%
Hypolimnion Water Temperature (°C)[E]	0.1	374	9.3	9.3	6.1	13.5	18.3[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	1,162	9.1	8.7	6.0	12.3	6[1,6,8], 7[1,6,8]	0, 85	0%, 7%
Dissolved Oxygen (% Sat.)	0.1	1,162	88.6	92.2	56.5	108.7	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	787	9.3	8.9	6.3	12.3	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	374	8.7	8.5	6.0	11.4	6[1,6,8]	0	0%
Specific Conductance (umho/cm)	1	1,160	693	700	534	765	-----	-----	-----
pH (S.U.)	0.1	1,115	8.3	8.3	7.3	9.0	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	1,160	-----	1	n.d.	48	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	1,119	360	360	256	473	-----	-----	-----
Secchi Depth (in.)	1	25	157	154	70	252	-----	-----	-----
Alkalinity, Total (mg/l)	7	51	166	164	140	190	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	49	3.1	3.1	1.6	6.1	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	40	9	9	n.d.	20	-----	-----	-----
Chloride (mg/l)	1	41	10	10	9	13	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	629	-----	3	n.d.	18	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	24	-----	2	n.d.	16	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	47	492	469	410	842	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	51	-----	0.03	n.d.	0.17	3.1 [1,5,9], 1.4 [1,7,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	51	0.4	0.3	n.d.	1.3	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	51	-----	n.d.	n.d.	0.19	10[2,5]	0	0%
Nitrogen, Total (mg/l)	0.1	51	0.4	0.4	n.d.	1.3	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	49	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	51	-----	0.03	n.d.	0.19	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	51	-----	n.d.	n.d.	0.05	-----	-----	-----
Sulfate (mg/l)	1	47	200	207	163	223	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	51	-----	n.d.	n.d.	9	53[1,5], 30[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	24	-----	n.d.	n.d.	n.d.	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	25	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	0	0%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Plate 148. Summary of monthly (June through September) water quality conditions monitored in Oahe Reservoir near Cow Creek (site OAHLK1090DW) during the 3-year period 2005 through 2007.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	12	1577.1	1576.8	1570.9	1583.2	-----	-----	-----
Water Temperature (°C)	0.1	486	15.6	15.4	8.1	27.1	18.3[1,5]	150	31%
Hypolimnion Water Temperature (°C)[E]	0.1	169	10.3	10.3	8.1	13.9	18.3[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	486	8.1	8.1	6.1	10.3	6[1,6,8], 7[1,6,8]	0, 78	0%, 16%
Dissolved Oxygen (% Sat.)	0.1	486	84.9	86.8	59.2	102.8	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	317	8.1	8.1	6.2	10.0	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	169	8.1	8.3	6.1	10.3	6[1,6,8]	0	0%
Specific Conductance (umho/cm)	1	486	676	694	536	770	-----	-----	-----
pH (S.U.)	0.1	486	8.3	8.4	7.5	8.9	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	484	5.8	2.1	n.d.	79.9	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	486	359	553	274	468	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	486	-----	1	n.d.	39	-----	-----	-----
Secchi Depth (in)	1	12	139	137	60	228	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	12	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	0	0%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Plate 149. Summary of monthly (May through September) water quality conditions monitored in Lake Oahe near the confluence of the Cheyenne River (Site OAHLK1110DW) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	22	1588.1	1583.1	1570.9	1613.5	-----	-----	-----
Water Temperature (°C)	0.1	757	15.8	15.9	5.9	25.5	18.3[1,5]	234	20%
Hypolimnion Water Temperature (°C)[E]	0.1	207	11.7	11.8	7.6	15.4	18.3[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	757	8.3	8.2	3.4	11.8	6[1,6,8], 7[1,6,8]	56, 144	7%, 19%
Dissolved Oxygen (% Sat.)	0.1	757	86.4	91.4	33.9	113.3	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	551	8.7	8.3	5.4	11.8	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	206	7.3	7.0	3.4	13.6	6[1,6,8]	41	20%
Specific Conductance (umho/cm)	1	757	690	696	536	826	-----	-----	-----
pH (S.U.)	0.1	723	8.3	8.3	7.2	8.9	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	752	4	2	n.d.	37	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	757	354	342	245	466	-----	-----	-----
Secchi Depth (in.)	1	22	114	110	56	192	-----	-----	-----
Alkalinity, Total (mg/l)	7	47	160	160	133	180	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	45	3.3	3.2	1.3	6.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	36	11	11	n.d.	19	-----	-----	-----
Chloride (mg/l)	1	36	10	11	8	13	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	473	7	6	n.d.	43	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	22	-----	3	n.d.	15	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	46	490	469	414	754	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	47	-----	n.d.	n.d.	0.27	3.1 [1,5,9], 1.3 [1,7,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	47	0.4	0.4	n.d.	2.5	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	46	-----	n.d.	n.d.	0.40	10[2,5]	0	0%
Nitrogen, Total (mg/l)	0.1	46	0.5	0.4	n.d.	2.5	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	47	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	47	0.04	0.03	n.d.	0.25	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	47	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	45	498	200	148	231	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	46	-----	n.d.	n.d.	13	53[1,5], 30[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	22	-----	n.d.	n.d.	0.2	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	22	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	3	14%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Plate 150. Summary of monthly (June through September) water quality conditions monitored in Oahe Reservoir near Sutton Bay (site OAHLK1135DW) during the 3-year period 2005 through 2007.

	Monitoring Results[(A)]						Water Quality Standards Attainment		
Parameter	**Detection Limit[(B)]**	**No. of Obs.**	**Mean[(C)]**	**Median**	**Min.**	**Max.**	**State WQS Criteria[(D)]**	**No. of WQS Exceedances**	**Percent WQS Exceedance**
Pool Elevation (ft-msl)	0.1	11	1577.1	1576.9	1570.9	1583.2	-----	-----	-----
Water Temperature (°C)	0.1	317	18.7	18.6	10.5	25.4	18.3[(1,5)]	163	51%
Hypolimnion Water Temperature (°C)[(E)]	0.1	55	14.7	14.7	12.6	17.8	18.3[(1,5)]	0	0%
Dissolved Oxygen (mg/l)	0.1	317	7.4	7.8	3.5	9.7	6[(1,6,8)], 7[(1,6,8)]	50, 82	16%, 26%
Dissolved Oxygen (% Sat.)	0.1	316	83.1	88.5	35.9	107.3	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[(E)]	0.1	256	7.9	7.9	5.2	9.7	5[(3,6)]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[(E)]	0.1	61	5.4	4.8	3.5	8.0	6[(1,6,8)]	42	69%
Specific Conductance (umho/cm)	1	317	654	659	532	732	-----	-----	-----
pH (S.U.)	0.1	317	8.3	8.3	7.6	8.6	6.5[(1,2,6)], 9.0[(1,2,5)], 9.5[(4,5)]	0	0%
Turbidity (NTUs)	1	315	6.2	3.7	0.6	34.1	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	316	378	376	296	469	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	313	-----	1	n.d.	6	-----	-----	-----
Secchi Depth (in)	1	11	90	100	40	122	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[(F)]	-----	11	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	5	45%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Plate 151. Summary of monthly (June through September) water quality conditions monitored in Lake Oahe near Whitlocks Bay (Site OAHLK1153DW) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	22	1588.1	1583.0	1571.1	1613.5	-----	-----	-----
Water Temperature (°C)	0.1	608	16.7	17.9	6.0	25.7	18.3[1,5]	280	46%
Hypolimnion Water Temperature (°C)[E]	0.1	156	13.0	12.8	8.3	19.9	18.3[1,5]	11	7%
Dissolved Oxygen (mg/l)	0.1	608	7.8	7.8	2.5	11.3	6[1,6,8], 7[1,6,8]	87, 124	14%, 20%
Dissolved Oxygen (% Sat.)	0.1	608	82.9	88.7	27.0	104.8	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	452	8.2	7.9	3.5	11.3	5[3,6]	6	1%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	156	6.6	7.3	2.5	9.8	6[1,6,8]	65	42%
Specific Conductance (umho/cm)	1	606	624	637	443	741	-----	-----	-----
pH (S.U.)	0.1	608	8.2	8.3	7.0	9.0	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	607	4	2	n.d.	24	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	608	377	374	259	516	-----	-----	-----
Secchi Depth (in.)	1	22	83	71	41	156	-----	-----	-----
Alkalinity, Total (mg/l)	7	46	155	156	103	180	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	44	3.4	3.2	1.6	6.9	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	36	12	12	n.d.	23	-----	-----	-----
Chloride (mg/l)	1	36	9	9	6	11	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	388	6	6	1	18	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	22	6	6	n.d.	16	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	46	452	431	340	684	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	46	-----	0.03	n.d.	0.31	3.1 [1,5,9], 1.2 [1,7,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	46	0.5	0.4	n.d.	1.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	46	-----	0.04	n.d.	0.40	10[2,5]	0	0%
Nitrogen, Total (mg/l)	0.1	46	0.69	0.5	n.d.	1.4	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	46	-----	0.02	n.d.	0.16	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	46	0.05	0.04	n.d.	0.23	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	46	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	44	168	165	111	207	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	46	-----	n.d.	n.d.	14	53[1,5], 30[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	22	-----	n.d.	n.d.	n.d.	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	22	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	10	45%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Plate 152. Summary of monthly (June through September) water quality conditions monitored in Oahe Reservoir near Swan Creek (site OAHLK1176DW) during the 3-year period 2005 through 2007.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	12	1577.1	1576.9	1571.1	1583.2	-----	-----	-----
Water Temperature (°C)	0.1	213	20.9	20.4	15.5	25.3	18.3[1,5]	169	79%
Hypolimnion Water Temperature (°C)[E]	0.1	5	19.6	19.4	18.6	21.2	18.3[1,5]	5	100%
Dissolved Oxygen (mg/l)	0.1	213	7.6	7.8	2.7	9.7	6[1,6,8], 7[1,6,8]	15, 34	7%, 16%
Dissolved Oxygen (% Sat.)	0.1	213	88.7	90.2	31.4	110.7	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	208	7.7	7.8	4.5	9.7	5[3,6]	3	1%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	5	4.5	4.9	2.7	5.2	6[1,6,8]	5	100%
Specific Conductance (umho/cm)	1	213	649	659	529	763	-----	-----	-----
pH (S.U.)	0.1	213	8.4	8.4	7.8	8.7	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0, 14	0%, 7%
Turbidity (NTUs)	1	211	6.2	4.7	1.5	26.4	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	213	402	411	294	477	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	212	2	2	n.d.	11	-----	-----	-----
Secchi Depth (in)	1	12	59	55	37	92	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	12	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	9	75%

n.d. = Not detected.

[A] Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

[B] Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

[C] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[D] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

[E] A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

[F] Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Plate 153. Summary of monthly (June through September) water quality conditions monitored in Lake Oahe near Mobridge, South Dakota (Site OAHLK1196DW) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	22	1588.1	1583.0	1571.1	1613.6	-----	-----	-----
Water Temperature (°C)	0.1	354	18.6	19.8	7.1	26.4	18.3[1,5]	236	67%
Hypolimnion Water Temperature (°C)[E]	0.1	18	12.6	13.1	10.8	14.2	18.3[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	354	7.8	7.9	2.8	10.8	6[1,6,8], 7[1,6,8]	23, 53	6%, 15%
Dissolved Oxygen (% Sat.)	0.1	354	86.9	89.7	27.3	108.3	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	335	8.0	8.0	4.1	10.8	5[3,6]	3	1%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	17	4.9	4.6	2.8	7.3	6[1,6,8]	11	65%
Specific Conductance (umho/cm)	1	354	598	638	331	749	-----	-----	-----
pH (S.U.)	0.1	354	8.2	8.4	7.2	8.7	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	352	12	9	1	55	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	354	382	379	262	519	-----	-----	-----
Secchi Depth (in.)	1	22	44	37	11	96	-----	-----	-----
Alkalinity, Total (mg/l)	7	38	153	162	88	180	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	35	3.5	3.3	2.6	5.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	30	13	12	9	22	-----	-----	-----
Chloride (mg/l)	1	30	8	9	4	11	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	232	14	10	2	61	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	21	10	7	1	61	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	38	458	443	246	692	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	38	-----	0.05	n.d.	0.47	2.6 [1,5,9], 0.87 [1,7,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	38	0.6	0.5	n.d.	2.5	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	38	-----	0.03	n.d.	0.50	10[2,5]	0	0%
Nitrogen, Total (mg/l)	0.1	38	0.7	0.5	n.d.	2.5	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	38	-----	0.02	n.d.	0.09	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	38	0.05	0.05	n.d.	0.15	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	38	-----	n.d.	n.d.	0.06	-----	-----	-----
Sulfate (mg/l)	1	36	160	164	70	200	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	38	-----	6	n.d.	18	53[1,5], 30[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	22	-----	n.d.	n.d.	0.2	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	22	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	16	73%

n.d. = Not detected.

[A] Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

[B] Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

[C] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[D] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for the protection of coldwater permanent fish life propagation waters.
- [2] Criteria for the protection of domestic water supply waters.
- [3] Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- [4] Criteria for the protection of commerce and industry waters.
- [5] Daily maximum criterion (monitoring results directly comparable to criterion).
- [6] Daily minimum criterion (monitoring results directly comparable to criterion).
- [7] 30-day average criterion (monitoring results not directly comparable to criterion).
- [8] The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- [9] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

[E] A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

[F] Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile. (Note: 2009 was the only year where Lake Oahe thermally stratified to the degree that a "true" hypolimnion formed during the summer.)

Plate 154. Summary of monthly (June through September) water quality conditions monitored in Lake Oahe near Beaver Creek (Site OAHLK1256DW) during 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	4	1611.7	1612.2	1609.1	1613.4	-----	-----	-----
Water Temperature (°C)	0.1	44	19.0	20.2	14.3	20.4	18.3(1,5)	35	80%
Hypolimnion Water Temperature (°C)[E]	0.1	2	14.5	14.5	14.3	14.7	18.3(1,5)	0	0%
Dissolved Oxygen (mg/l)	0.1	44	8.4	7.9	7.1	9.7	6(1,6,8), 7(1,6,8)	0	0%
Dissolved Oxygen (% Sat.)	0.1	44	92.9	91.3	81.7	105.3	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	42	8.3	7.9	7.1	9.7	5(3,6)	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	2	9.6	9.6	9.5	9.6	6(1,6,8)	0	0%
Specific Conductance (umho/cm)	1	44	628	628	602	659	-----	-----	-----
pH (S.U.)	0.1	44	8.1	8.1	7.9	8.4	6.5(1,2,6), 9.0(1,2,5), 9.5(4,5)	0	0%
Turbidity (NTUs)	1	44	7	7	3	12	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	44	389	340	334	495	-----	-----	-----
Secchi Depth (in.)	1	4	42	38	32	58	-----	-----	-----
Alkalinity, Total (mg/l)	7	4	159	160	154	163	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	4	3.1	3.1	2.2	3.9	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	4	11	11	10	13	-----	-----	-----
Chloride (mg/l)	1	4	10	11	8	11	175(1,5), 100(1,7), 438(2,5), 250(2,7)	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	44	23	24	12	29	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	4	21	23	13	26	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	4	491	466	400	632	1,750(2,5), 1,000(2,7), 3,500(4,5), 2,000(4,7)	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	4	-----	0.03	n.d.	0.03	3.1 (1,5,9), 1.4 (1,7,9)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	4	0.8	0.8	0.6	1.2	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	4	-----	0.02	n.d.	0.03	10(2,5)	0	0%
Nitrogen, Total (mg/l)	0.1	4	0.8	0.8	0.6	1.2	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	4	-----	n.d.	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	4	0.05	0.04	0.03	0.08	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	4	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	4	155	157	144	163	875(2,5), 500(2,7)	0	0%
Suspended Solids, Total (mg/l)	4	4	-----	9	n.d.	17	53(1,5), 30(1,7)	0	0%
Microcystin, Total (ug/l)	0.2	4	-----	n.d.	n.d.	0.1	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	4	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	3	75%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

(G) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

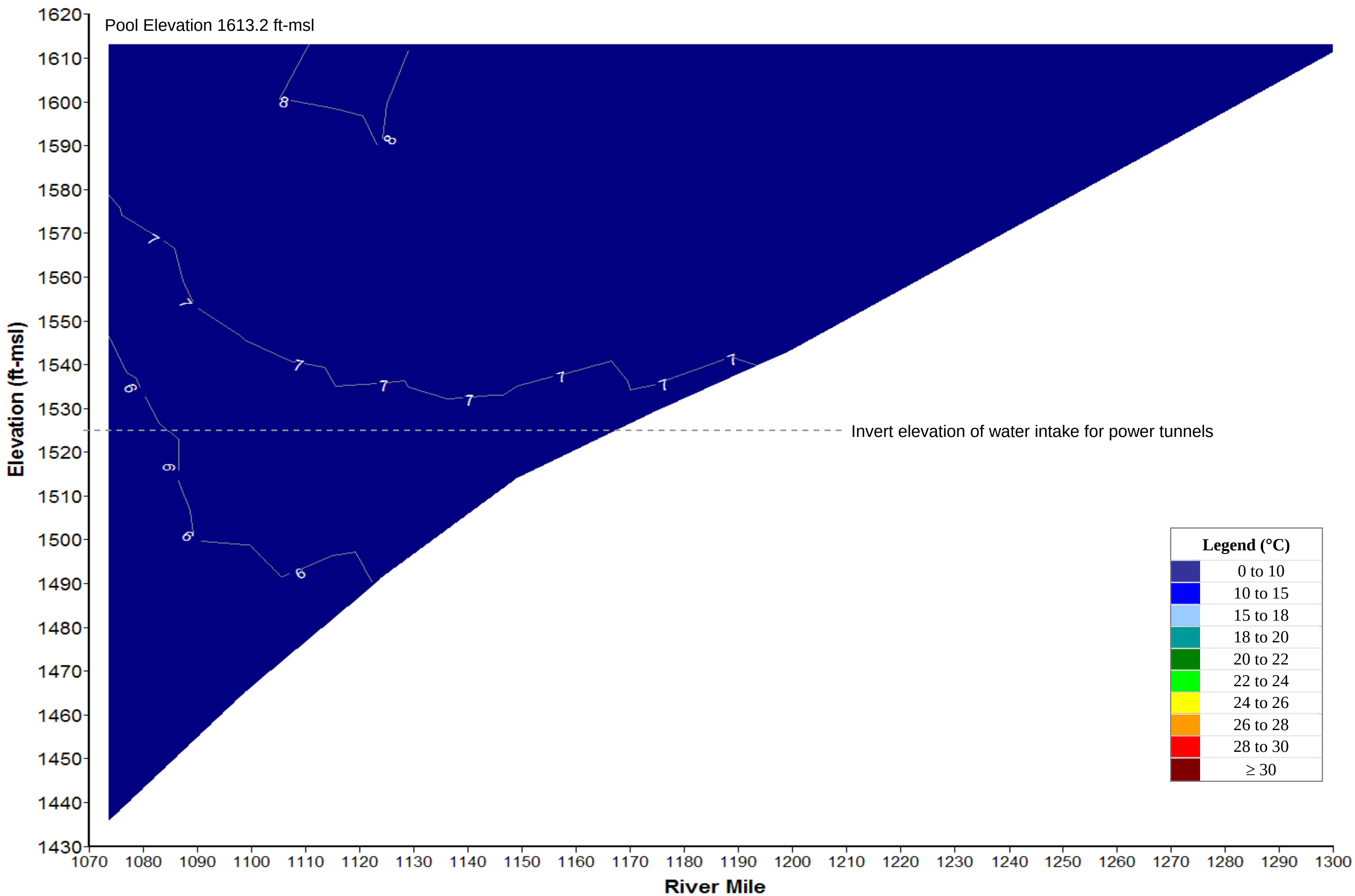


Plate 155. Longitudinal water temperature (°C) contour plot of Lake Oahe based on depth-profile water temperatures measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on May 13, 2009.

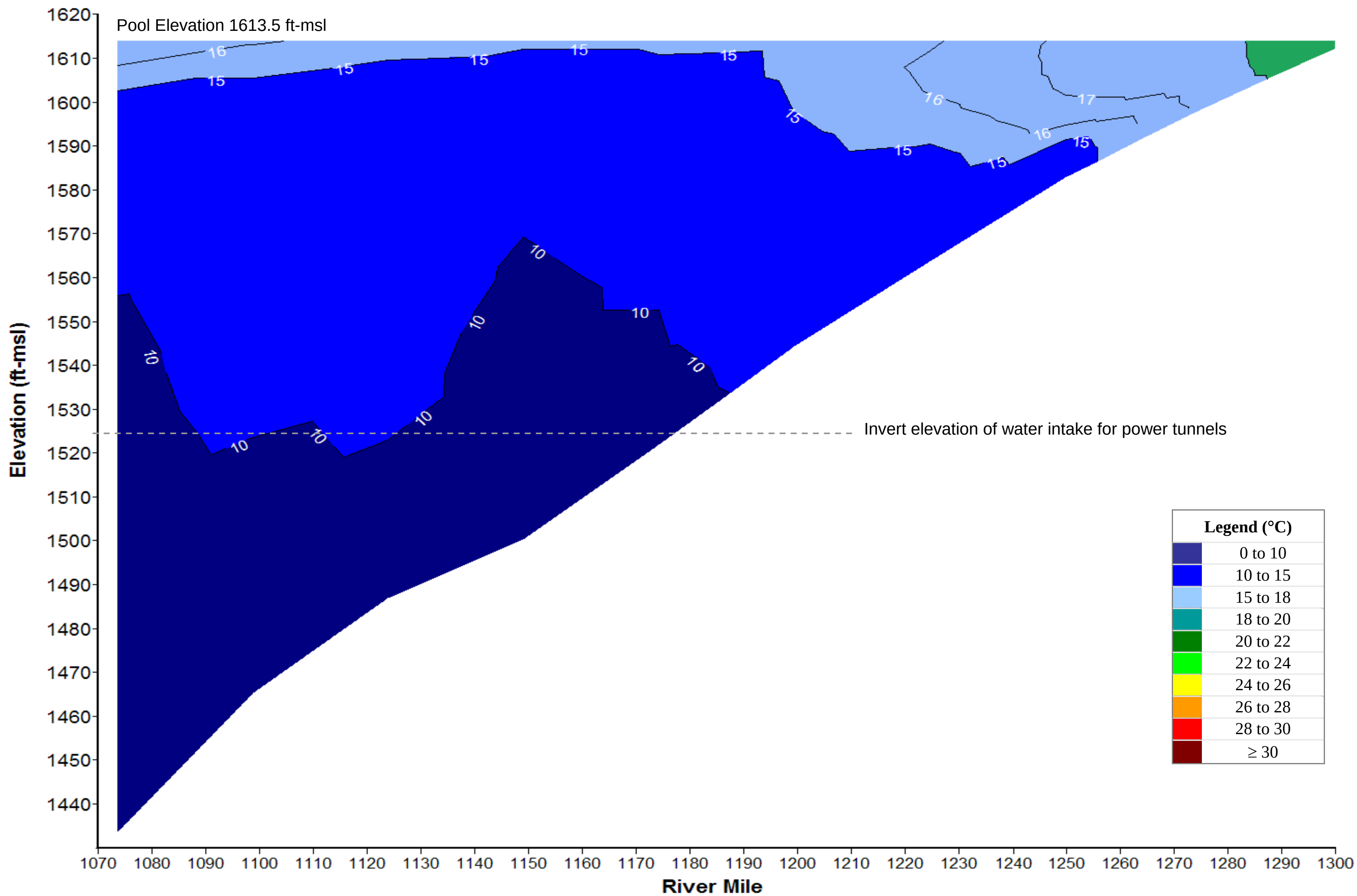


Plate 156. Longitudinal water temperature (°C) contour plot of Lake Oahe based on depth-profile water temperatures measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on June 16, 2009.

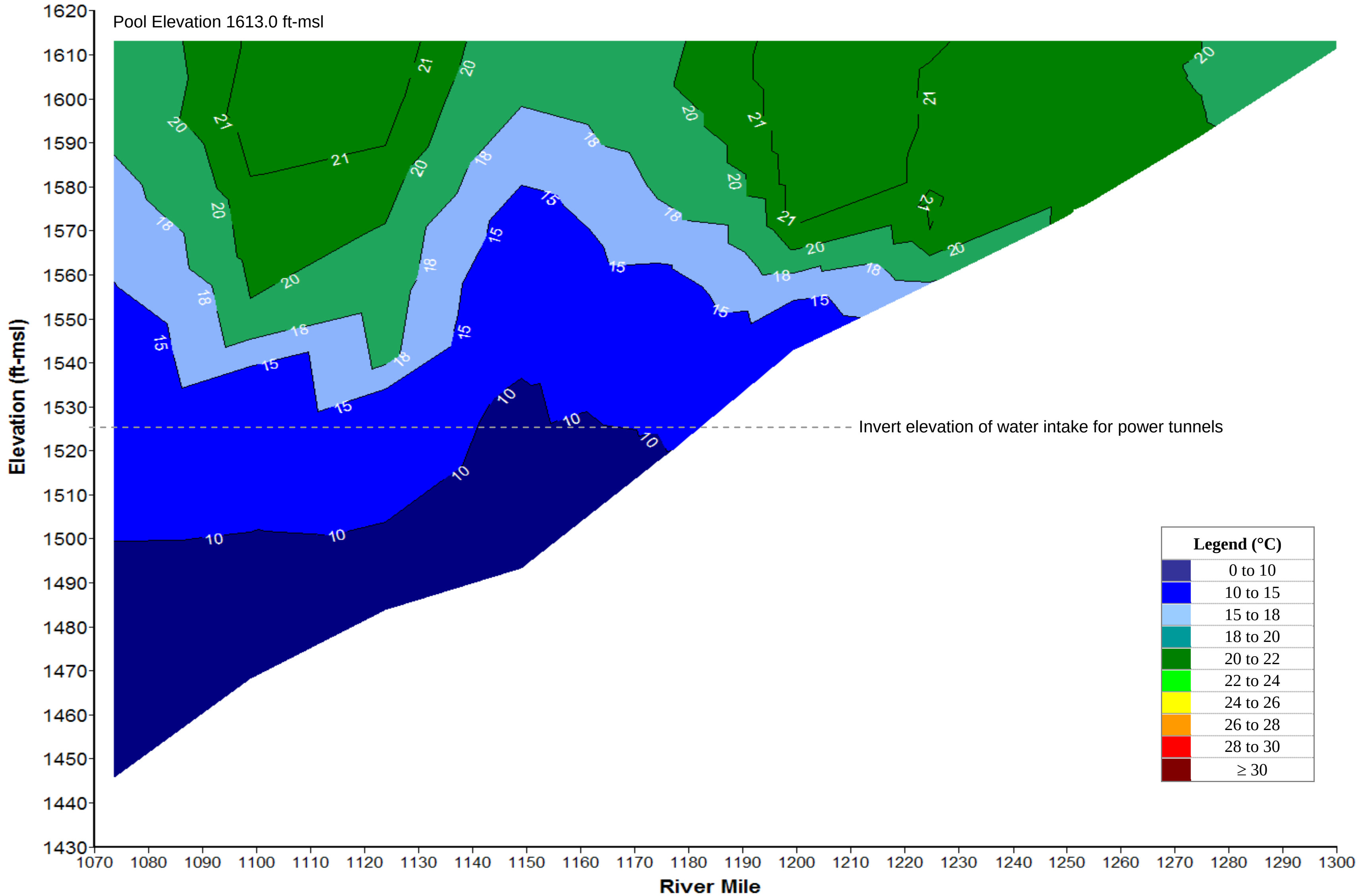


Plate 157. Longitudinal water temperature (°C) contour plot of Lake Oahe based on depth-profile water temperatures measured at sites OAHLK1073A, OAHLK1090DW, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on July 14, 2009.

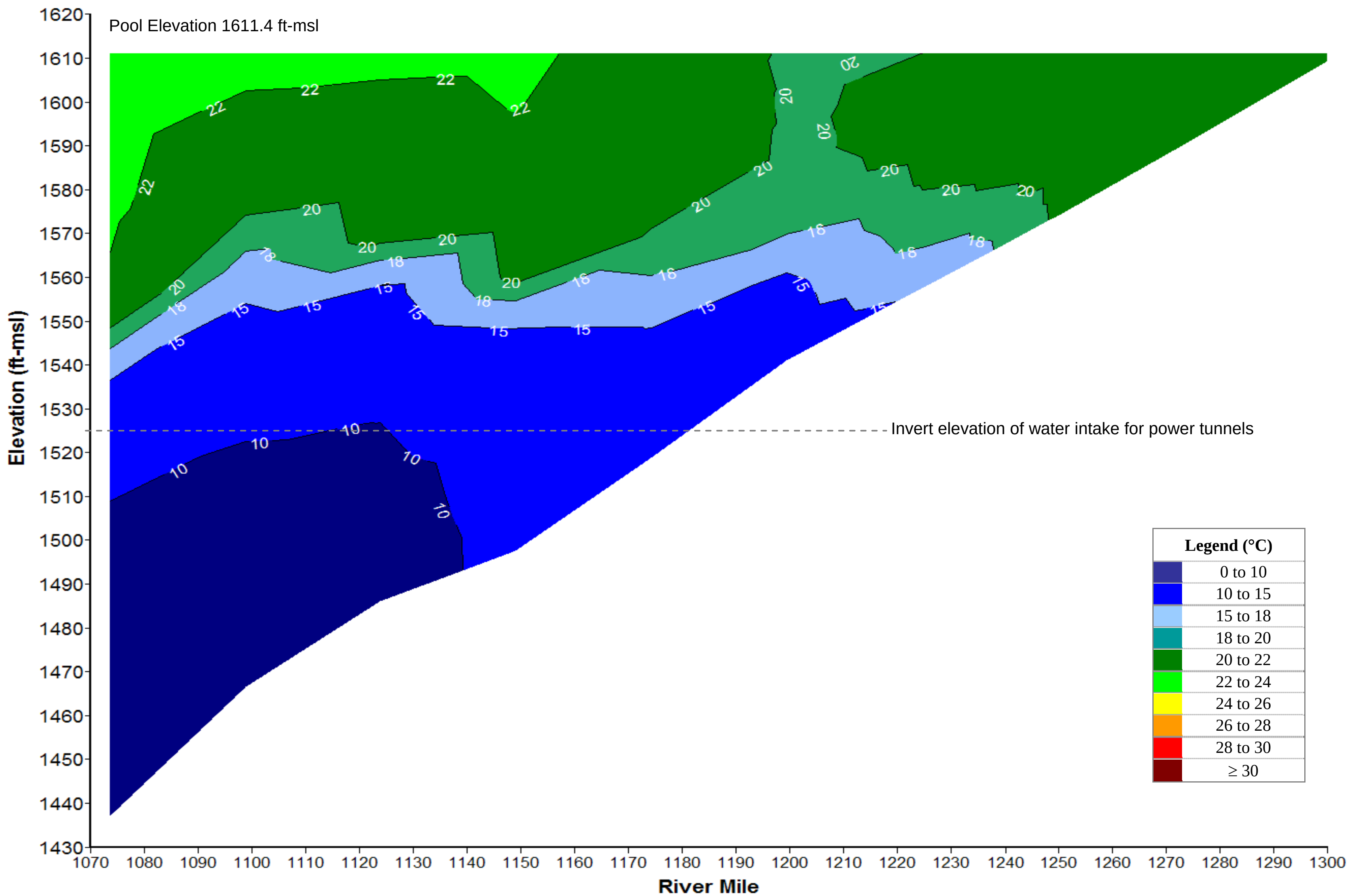


Plate 158. Longitudinal water temperature (°C) contour plot of Lake Oahe based on depth-profile water temperatures measured at sites OAHLK1073A, OAHLK1090DW, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on August 18, 2009.

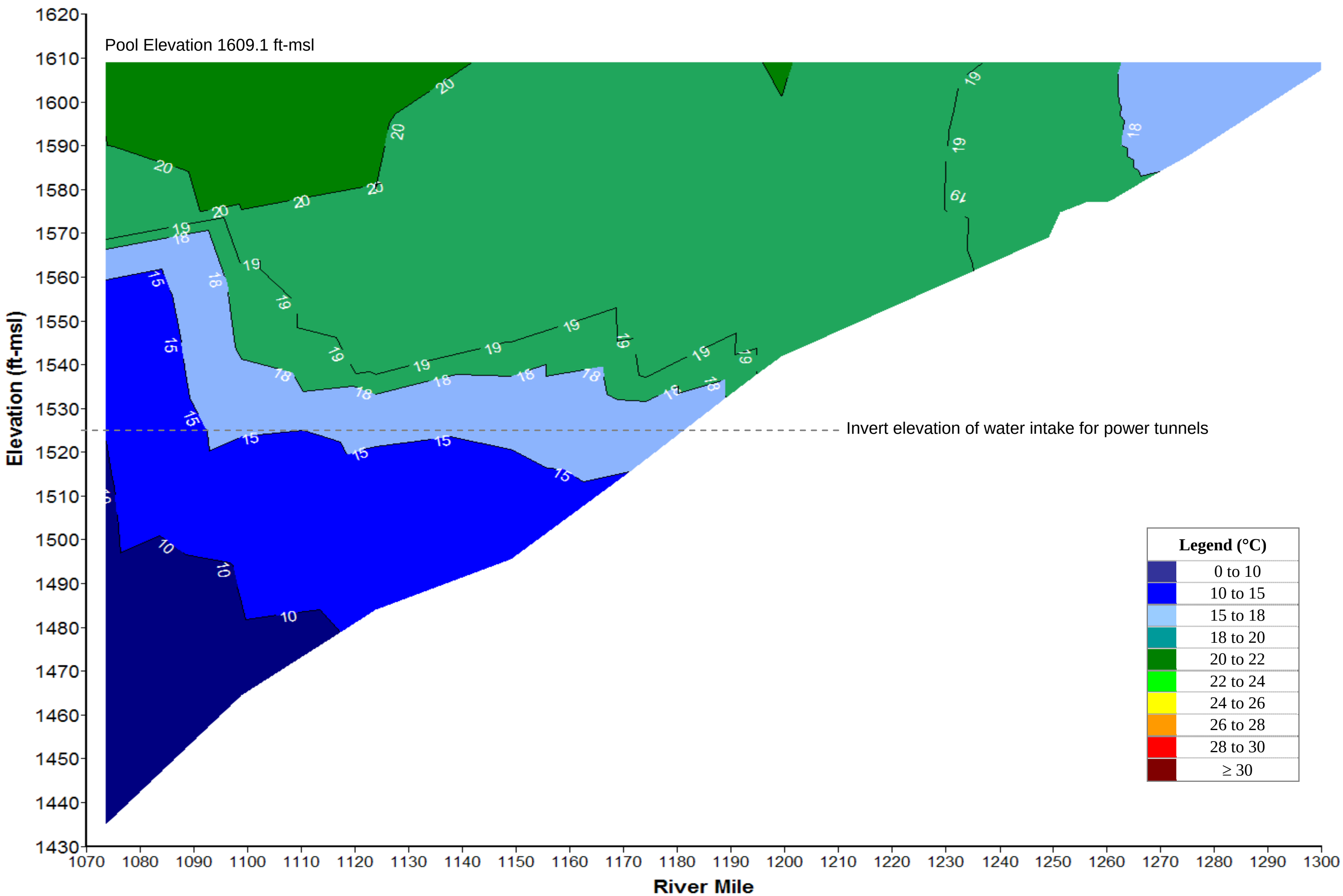


Plate 159. Longitudinal water temperature (°C) contour plot of Lake Oahe based on depth-profile water temperatures measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on September 15, 2009.

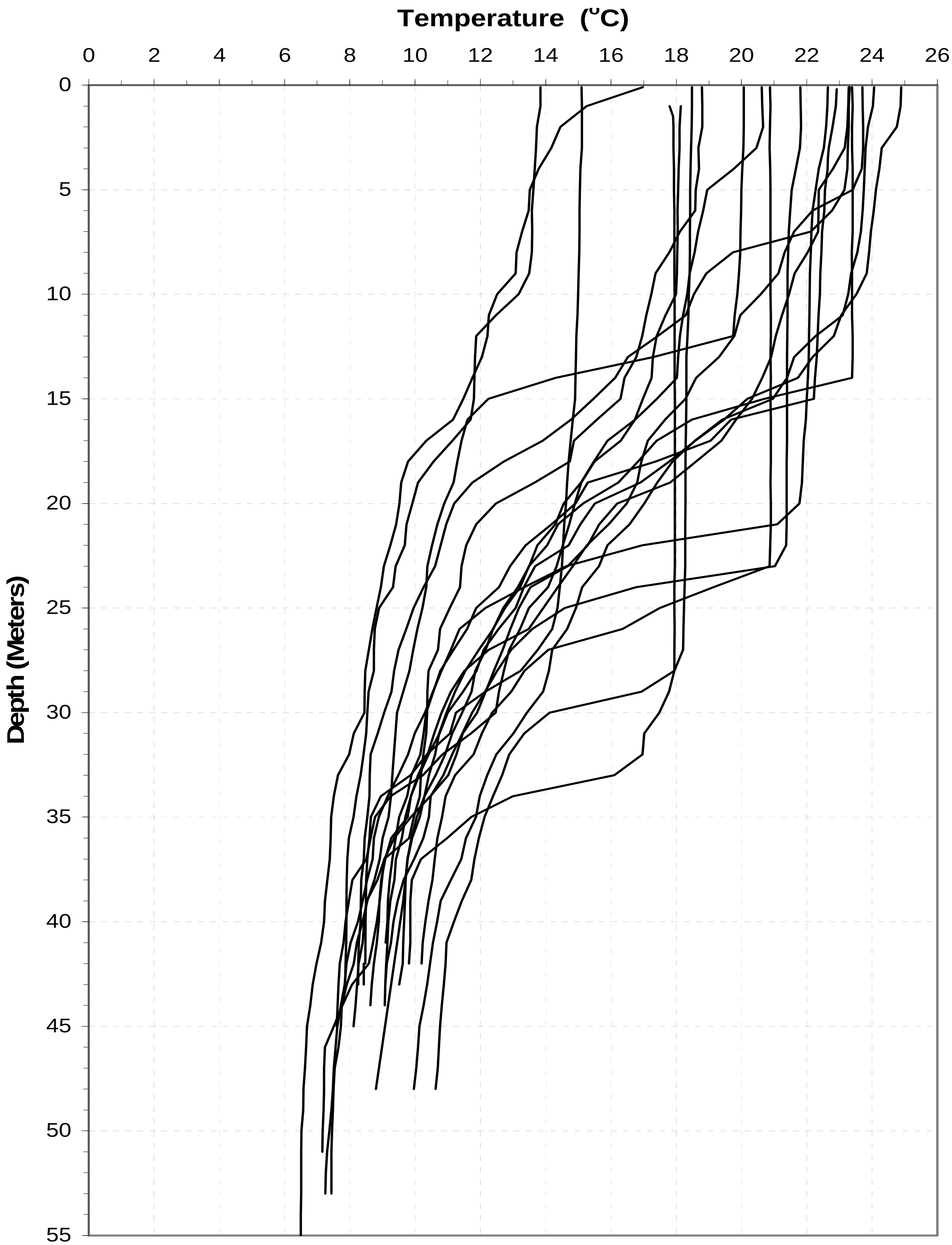


Plate 160. Temperature depth profiles for Lake Oahe generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., OAHLK1073A) during the summer months over the 5-year period of 2005 to 2009**.**

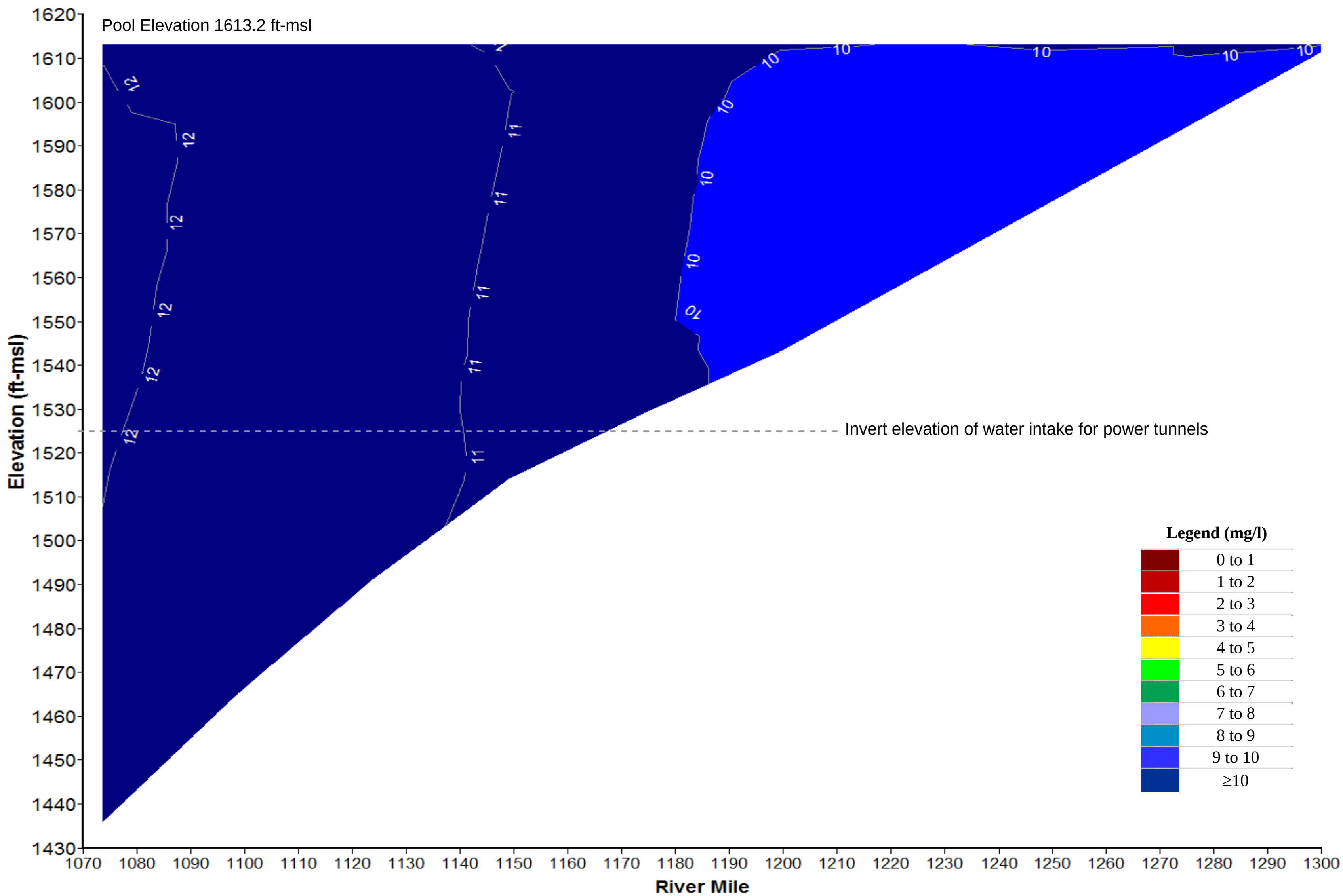


Plate 161. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Oahe based on depth-profile dissolved oxygen concentrations measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on May 13, 2009.

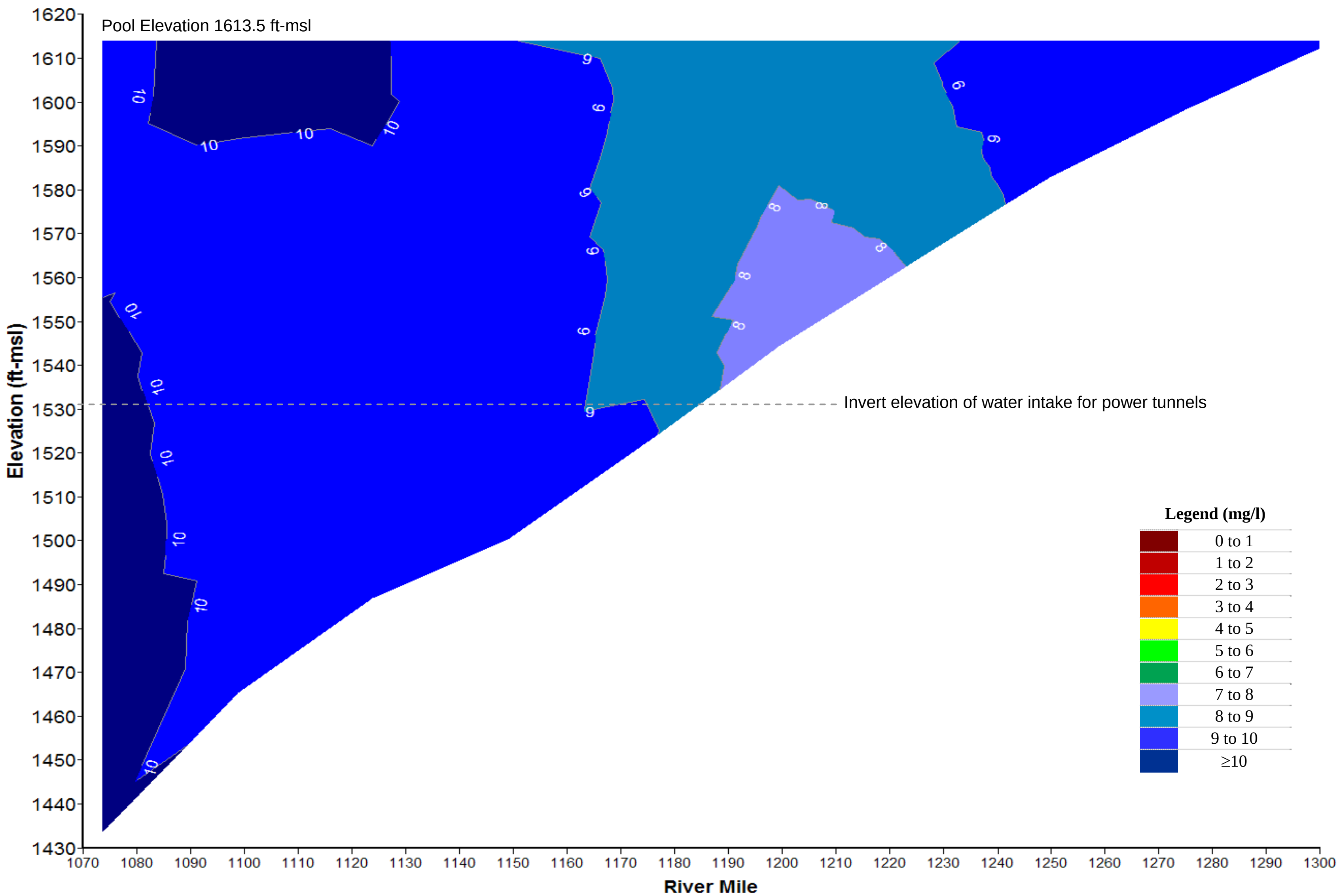


Plate 162. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Oahe based on depth-profile dissolved oxygen concentrations measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on June 16, 2009.

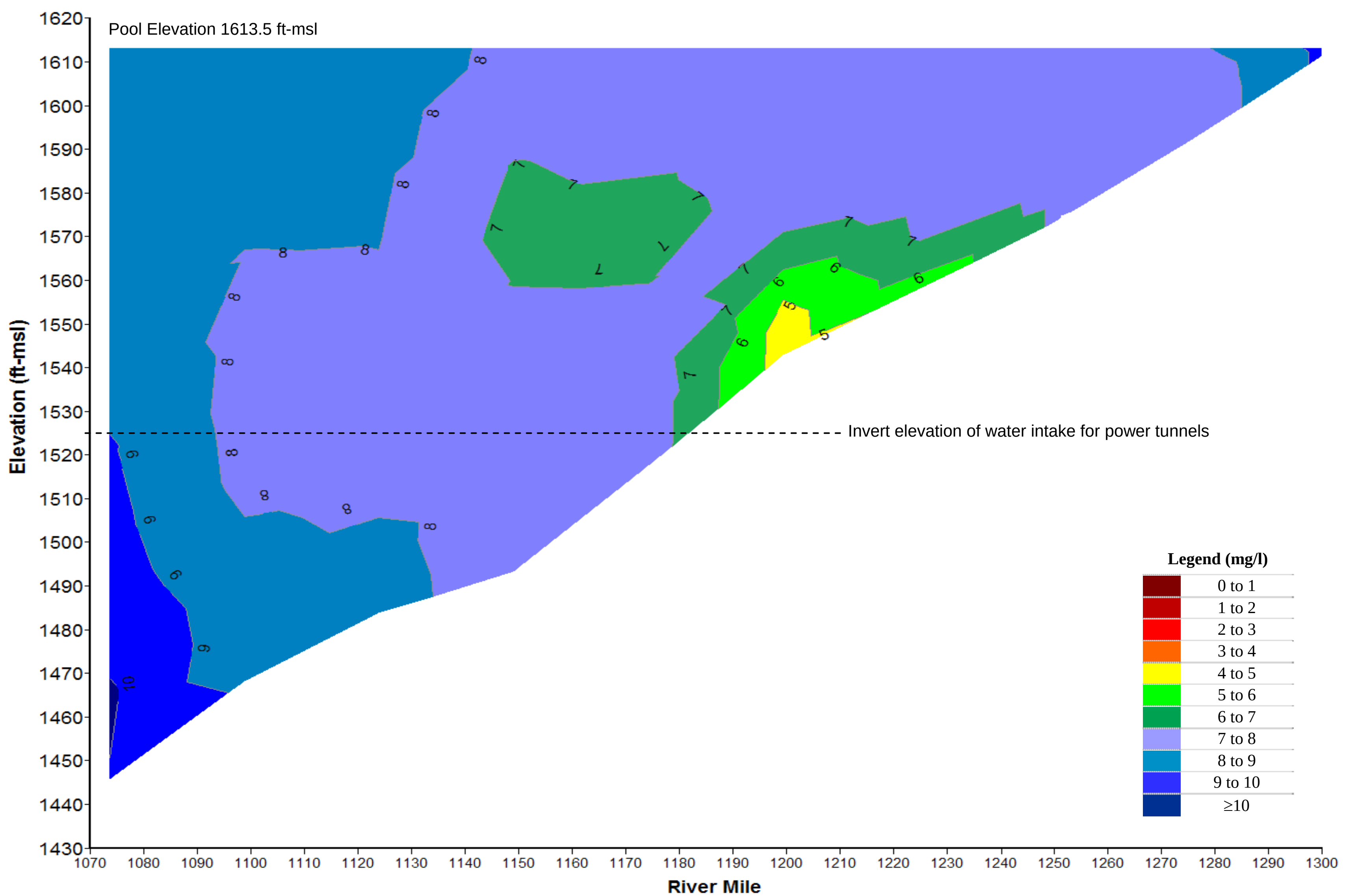


Plate 163. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Oahe based on depth-profile dissolved oxygen concentrations measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on July 14, 2009.

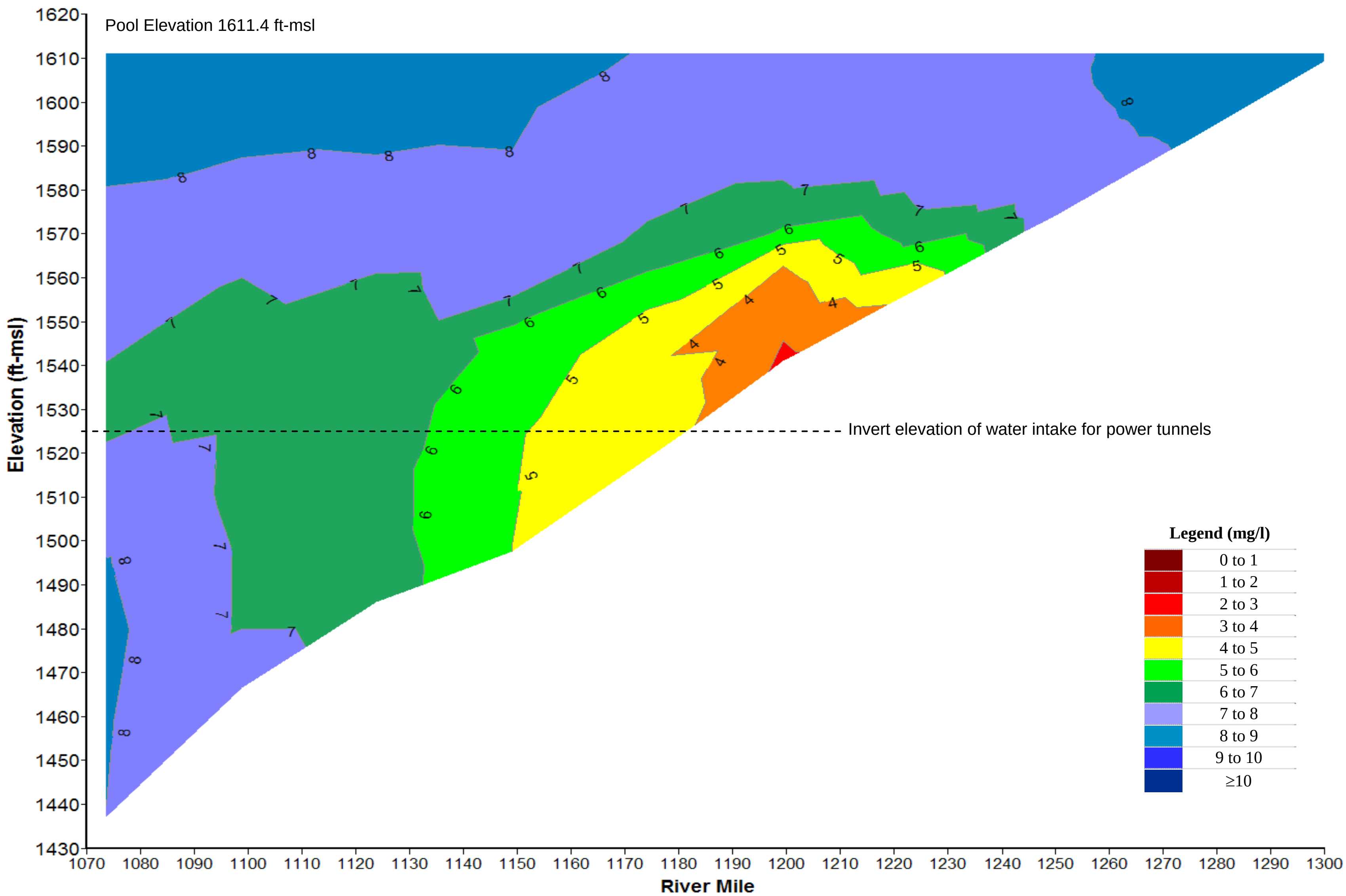


Plate 164. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Oahe based on depth-profile dissolved oxygen concentrations measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on August 18, 2009.

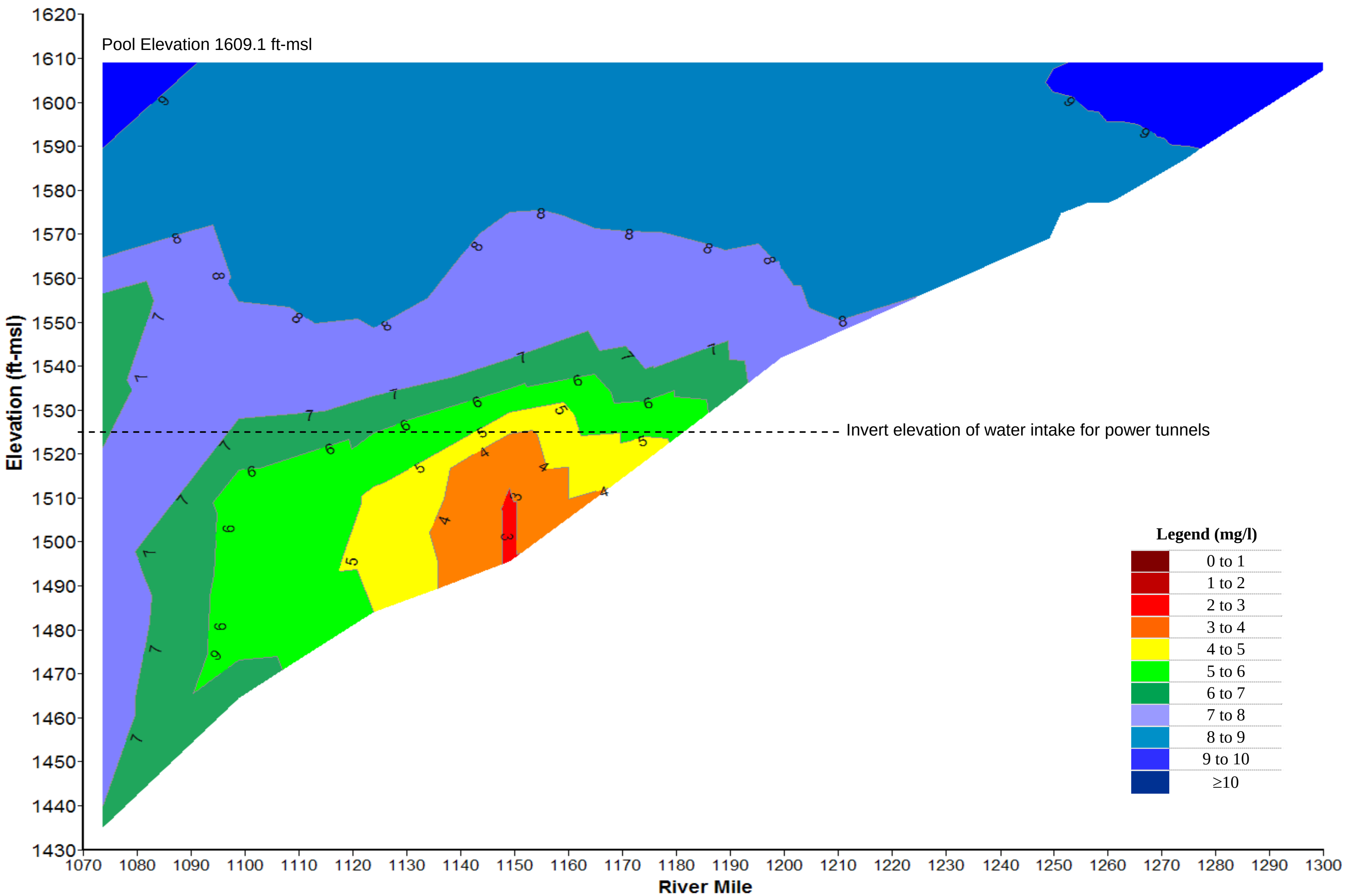


Plate 165. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Oahe based on depth-profile dissolved oxygen concentrations measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on September 15, 2009.

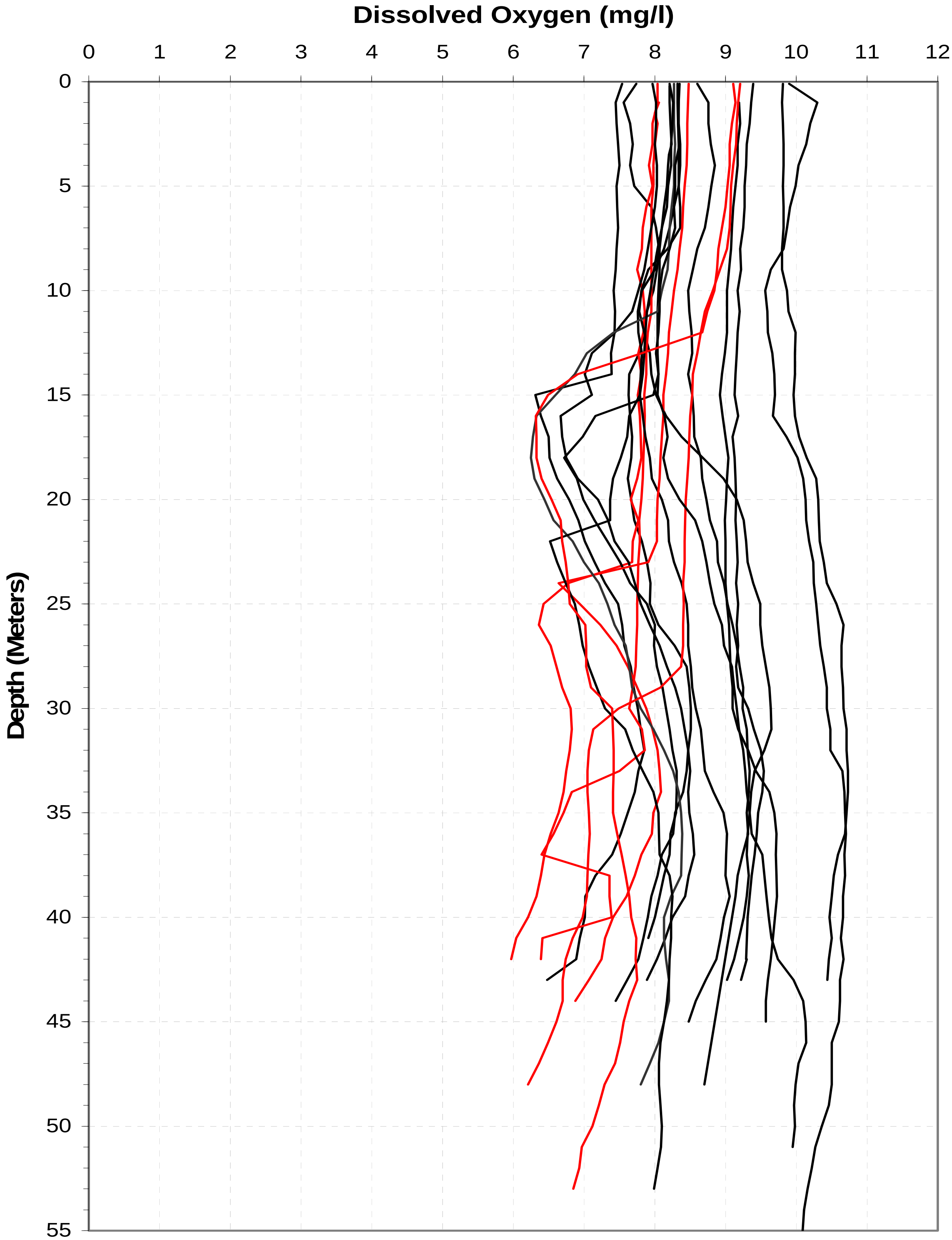


Plate 166. Dissolved oxygen depth profiles for Lake Oahe generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., OAHLK1073A) during the summer months of the 5-year period of 2005 to 2009.
(Note: Red profile plots were measured in the month of September.)

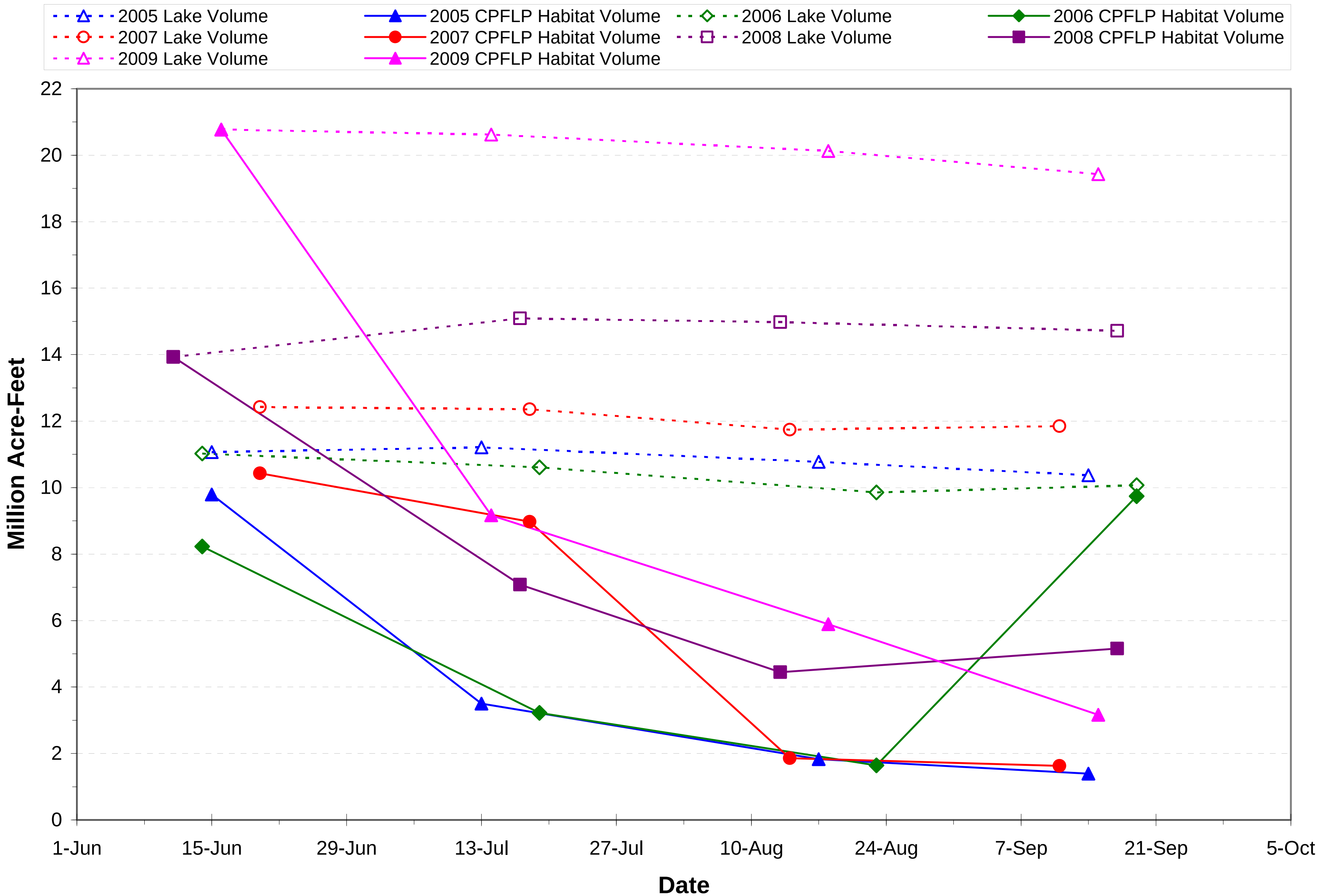


Plate 167. Estimated volume of Coldwater Permanent Fish Life Propagation habitat in Lake Oahe during 2005, 2006, 2007, 2008, and 2009.

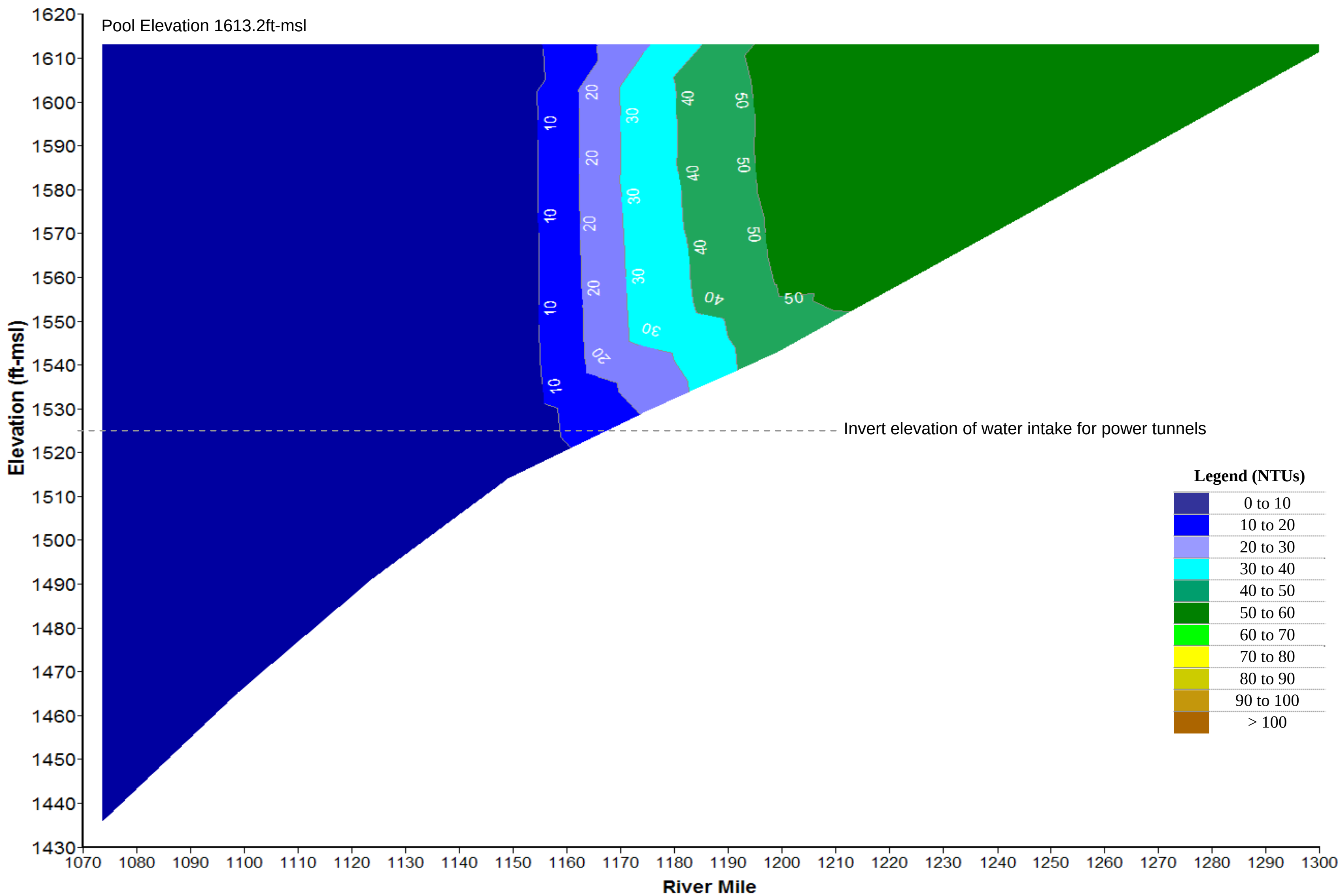


Plate 168. Longitudinal turbidity (NTU) contour plot of Lake Oahe based on depth-profile turbidity levels measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on May 13, 2009.

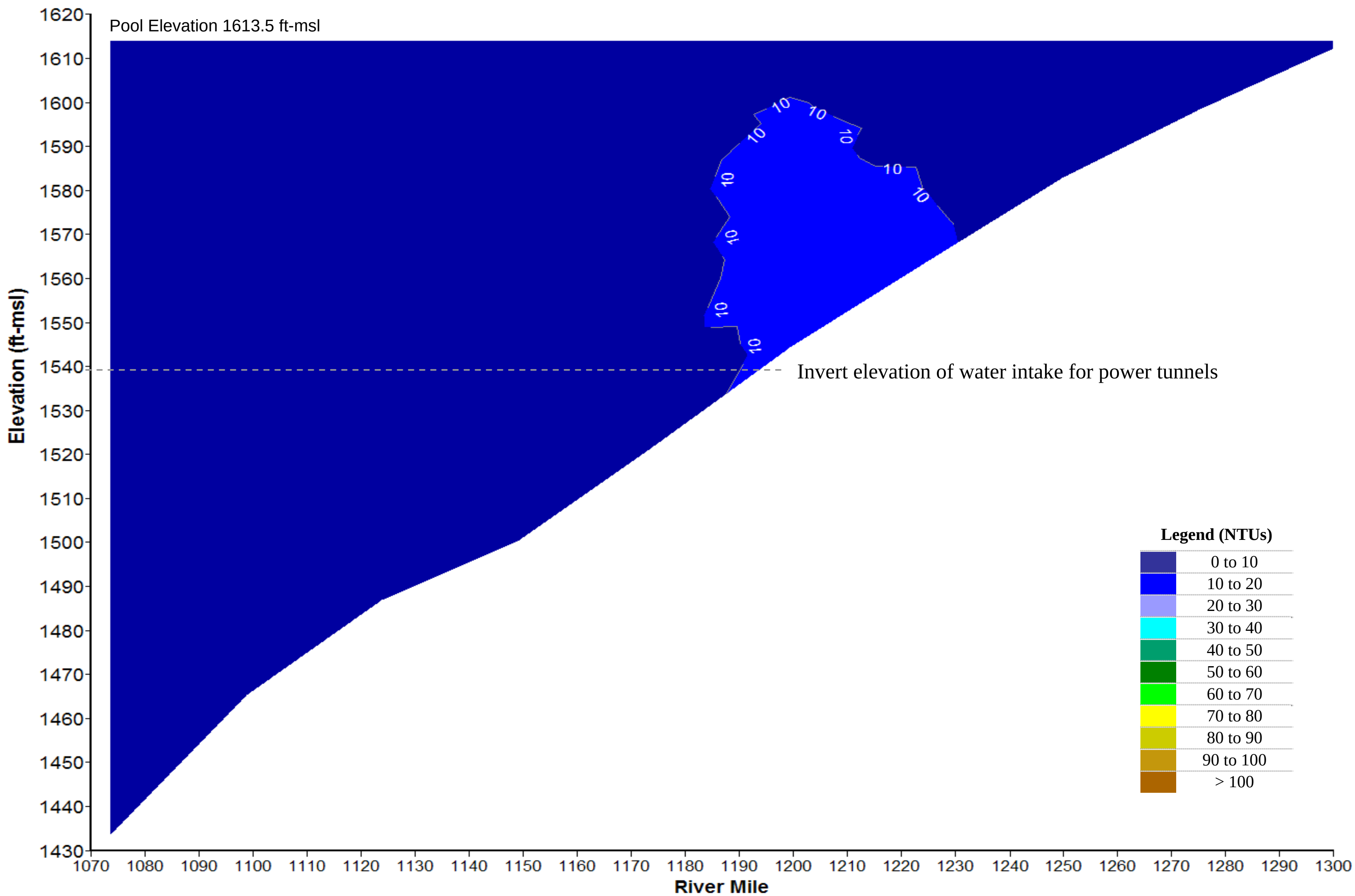


Plate 169. Longitudinal turbidity (NTU) contour plot of Lake Oahe based on depth-profile turbidity levels measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on June 16, 2009.

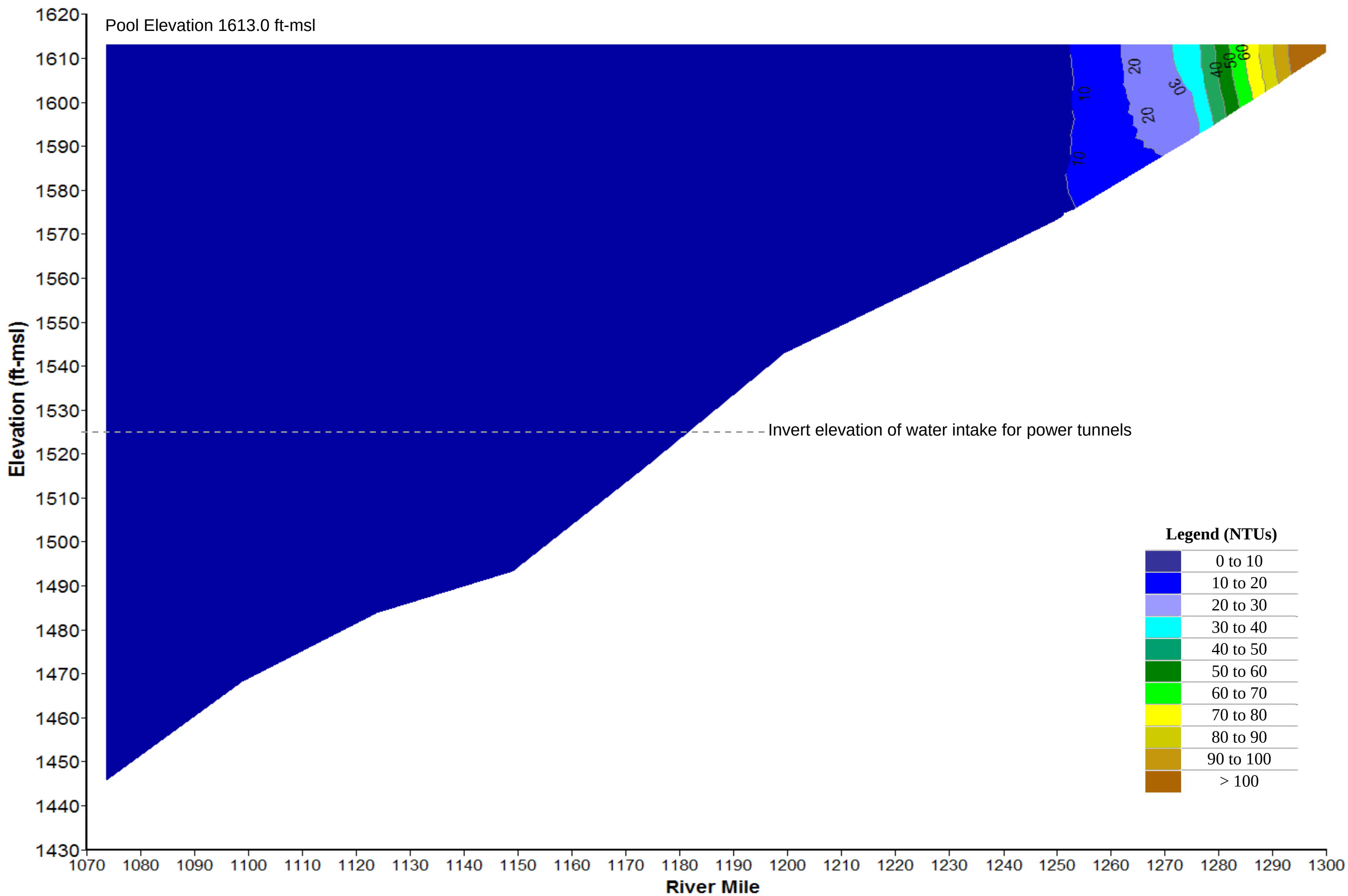


Plate 170. Longitudinal turbidity (NTU) contour plot of Lake Oahe based on depth-profile turbidity levels measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on July 14, 2009.

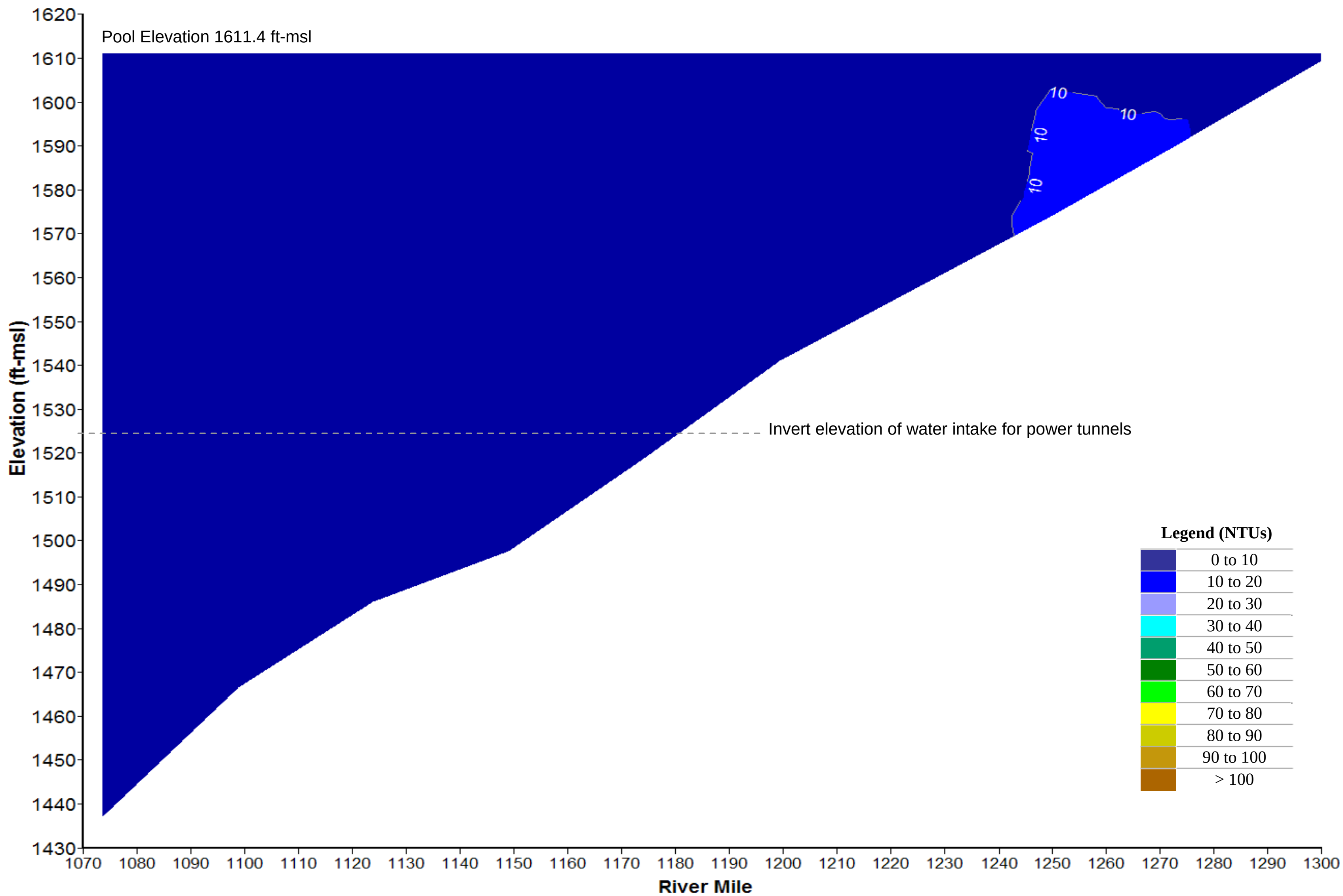


Plate 171. Longitudinal turbidity (NTU) contour plot of Lake Oahe based on depth-profile turbidity levels measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on August 18, 2009.

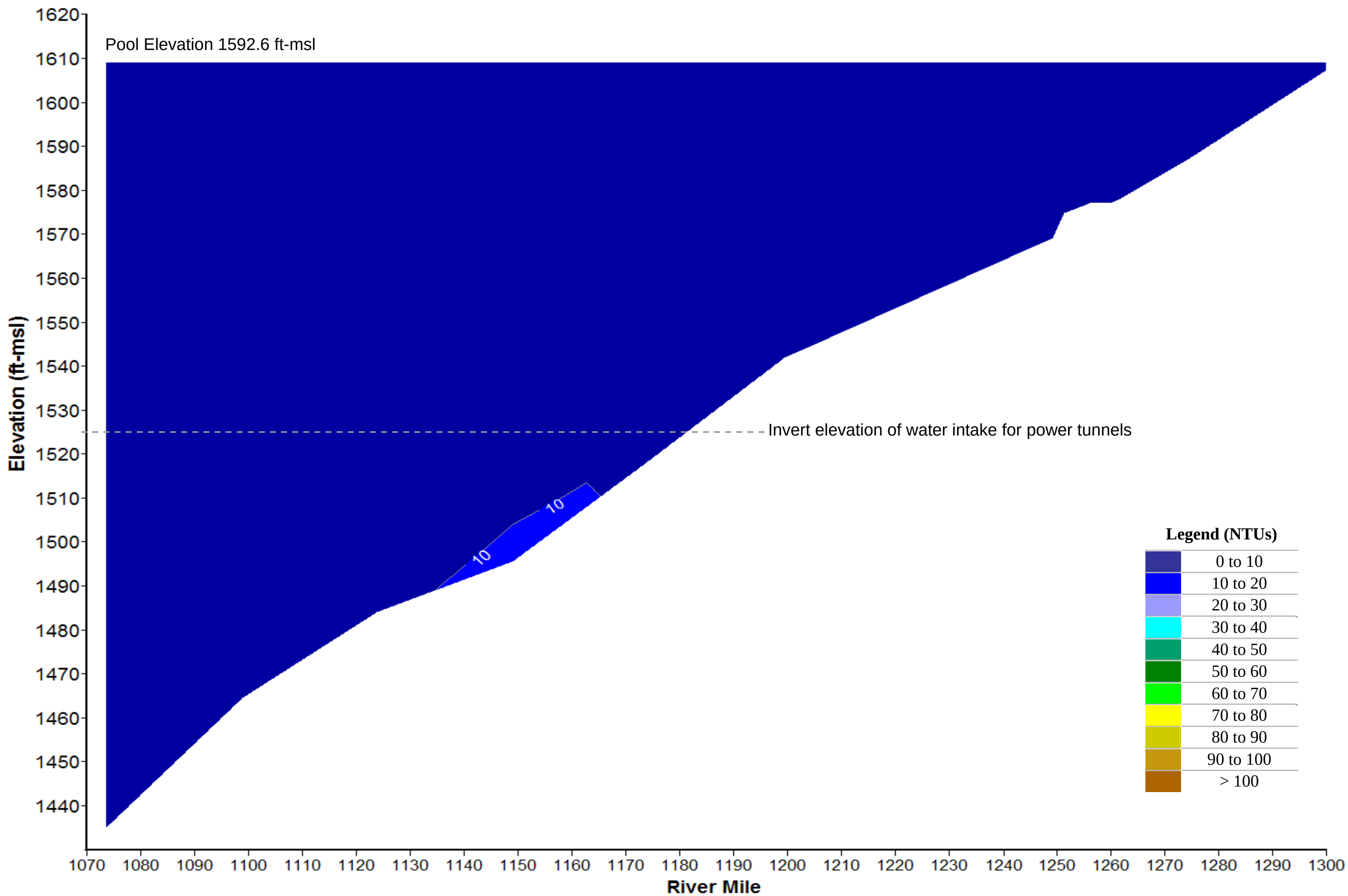


Plate 172. Longitudinal turbidity (NTU) contour plot of Lake Oahe based on depth-profile turbidity levels measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on September 15, 2009.

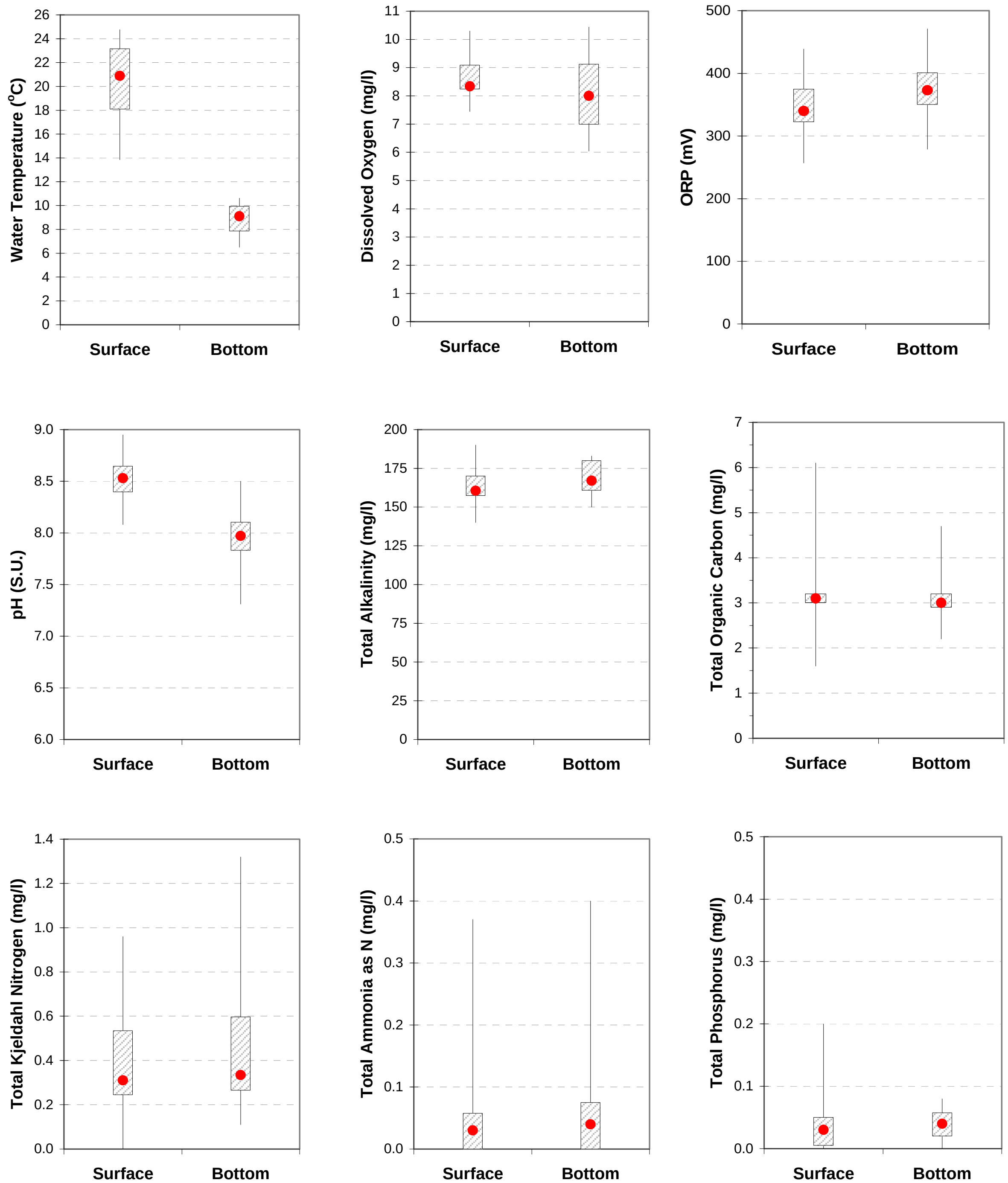


Plate 173. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Lake Oahe at site OAHLK1073A during the summer months of the 5-year period 2005 through 2009.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 174. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Oahe at site OAHLK1073A during the 5-year period 2005 through 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
May 2005	185,149,541	3	0.96	2	0.01	1	<0.01	1	0.03	0	-----	0	-----	0	-----	0.96
Jun 2005	55,201,496	4	0.58	1	0.8	0	-----	1	0.11	3	0.02	1	0.22	0	-----	1.78
Jul 2005	45,943,019	4	0.31	2	0.04	1	0.35	1	0.04	3	0.02	1	0.25	0	-----	1.73
Aug 2005	37,779,368	5	0.84	1	0.12	0	-----	0	-----	3	0.04	0	-----	0	-----	1.58
Sep 2005	100,194,654	9	0.46	7	0.09	2	0.14	2	0.04	4	0.22	1	0.05	0	-----	2.39
May 2006	186,720,908	8	0.97	3	0.01	0	-----	1	0.01	0	-----	1	0.02	0	-----	1.31
Jun 2006	95,437,433	5	0.76	6	0.18	0	-----	1	0.05	0	-----	0	-----	1	0.01	1.52
Jul 2006	21,592,424	4	0.17	8	0.46	0	-----	1	0.29	2	0.08	0	-----	0	-----	2.25
Aug 2006	52,731,261	5	0.42	2	0.06	1	0.08	1	0.11	3	0.11	1	0.22	0	-----	2.05
Sep 2006	72,290,329	5	0.12	7	0.26	0	-----	1	0.17	2	0.26	1	0.19	0	-----	2.06
May 2007	116,487,228	7	0.69	5	0.16	2	0.04	1	0.10	0	-----	1	0.01	0	-----	2.09
Jun 2007	688,764,256	4	0.85	6	0.03	2	0.09	1	0.02	0	-----	2	0.02	0	-----	1.03
Jul 2007	112,682,481	9	0.71	7	0.04	0	-----	1	0.12	0	-----	2	0.12	0	-----	1.52
Aug 2007	45,414,995	3	0.04	7	0.08	1	0.11	1	0.35	2	0.07	1	0.35	0	-----	1.63
Sep 2007	211,489,007	5	0.40	10	0.03	1	0.11	2	0.01	5	0.03	1	0.41	0	-----	1.45
May 2008	232,958,831	6	0.96	3	<0.01	0	-----	1	0.03	0	-----	0	-----	0	-----	1.00
Jun 2008	224,849,023	10	0.96	3	0.01	1	<0.01	1	0.02	0	-----	1	0.01	0	-----	0.95
Jul 2008	187,175	6	0.85	5	0.03	1	0.02	0	-----	0	-----	1	0.09	0	-----	1.17
Aug 2008	13,908,908	2	0.03	3	0.18	1	0.32	1	0.45	2	0.01	0	-----	0	-----	1.31
Sep 2008	273,503,287	8	0.80	11	0.03	2	0.01	2	0.07	2	0.01	2	0.09	1	<0.01	0.98
May 2009	4,647,400,810	7	0.93	3	<0.01	0	-----	2	0.06	1	0.01	0	-----	0	-----	0.79
Jun 2009	2,890,368,436	4	0.97	2	<0.01	2	<0.01	2	0.02	0	-----	0	-----	0	-----	0.23
Jul 2009	2,076,075,290	14	0.71	9	0.11	0	-----	2	0.01	2	<0.01	2	0.16	2	<0.01	1.52
Aug 2009	211,687,685	6	0.38	5	0.02	1	0.05	1	0.19	2	<0.01	1	0.35	0	-----	1.55
Sep 2009	1,374,203,069	4	0.52	4	0.01	1	0.05	2	0.24	7	0.04	1	0.14	0	-----	1.91
Mean*	**558,920,837**	**5.9**	**0.62**	**4.9**	**0.11**	**0.8**	**0.09**	**1.2**	**0.11**	**1.7**	**0.06**	**0.8**	**0.16**	**0.2**	**<0.01**	**1.47**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 175. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Oahe at site OAHLK1110DW during the 5-year period 2005 through 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2005	312,053,421	4	0.84	3	0.08	1	<0.01	2	0.06	4	0.02	0	-----	0	-----	1.06
Aug 2005	140,479,427	6	0.30	2	0.08	1	0.07	1	0.29	2	0.05	2	0.22	0	-----	2.16
Sep 2005	162,991,360	5	0.35	4	0.08	1	<0.01	2	0.10	4	0.25	2	0.22	0	-----	2.02
Jun 2006	546,334,257	6	0.97	5	0.01	2	<0.01	1	0.02	3	<0.01	1	<0.01	0	-----	0.64
Jul 2006	83,678,531	6	0.14	3	0.22	0	-----	1	0.19	4	0.20	2	0.24	0	-----	2.19
Aug 2006	300,970,747	6	0.46	5	0.09	0	-----	1	<0.01	3	0.41	1	0.04	0	-----	1.88
Sep 2006	168,663,712	6	0.22	15	0.30	1	0.02	1	0.30	3	0.04	2	0.12	2	<0.01	2.53
Jun 2007	2,874,771,946	6	0.88	7	0.01	2	0.07	1	0.01	0	-----	1	0.03	0	-----	1.05
Jul 2007	61,788,273	8	0.14	6	0.13	1	0.38	1	0.13	1	0.01	1	0.22	0	-----	1.80
Aug 2007	189,011,871	7	0.31	10	0.10	0	-----	1	0.09	1	0.30	1	0.20	1	<0.01	1.99
Sep 2007	127,037,794	5	0.13	8	0.06	1	0.02	1	0.06	6	0.16	1	0.56	1	0.01	1.75
May 2008	419,015,484	7	0.97	1	<0.01	1	<0.01	1	0.03	0	-----	1	<0.01	0	-----	0.65
Jun 2008	455,034,524	11	0.97	8	0.01	2	<0.01	1	0.01	2	<0.01	0	-----	0	-----	1.28
Jul 2008	199,124	3	0.67	12	0.14	1	0.07	1	0.06	0	-----	3	0.06	0	-----	1.71
Aug 2008	93,145,243	2	0.86	2	<0.01	1	<0.01	1	0.07	3	0.01	2	0.05	0	-----	0.60
Sep 2008	198,239,601	8	0.46	6	0.06	1	0.01	2	0.32	2	0.04	1	0.11	1	<0.01	1.74
May 2009	2,057,875,445	7	0.68	3	0.10	0	-----	2	0.22	1	<0.01	1	<0.01	0	-----	1.56
Jun 2009	1,090,780,416	5	0.79	2	0.07	2	<0.01	1	0.14	0	-----	0	-----	0	-----	1.33
Jul 2009	1,335,734,876	8	0.57	7	0.36	0	-----	1	0.02	1	<0.01	2	0.06	1	<0.01	1.30
Aug 2009	414,972,663	4	0.23	6	0.17	1	0.01	2	0.47	2	0.08	1	0.03	1	<0.01	1.88
Sep 2009	1,866,820,914	4	0.06	8	0.03	1	<0.01	2	0.17	5	0.05	1	0.65	1	<0.01	1.32
Mean*	**614,266,649**	**5.9**	**0.52**	**5.9**	**0.11**	**1.0**	**0.04**	**1.3**	**0.13**	**2.2**	**0.10**	**1.2**	**0.16**	**0.4**	**<0.01**	**1.54**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 176. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Oahe at site OAHLK1153DW during the 5-year period 2005 through 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2005	2,103,413	0	-----	0	-----	0	-----	2	0.83	2	0.17	0	-----	0	-----	0.55
Jul 2005	121,465,212	5	0.44	2	0.02	1	0.50	2	0.04	2	<0.01	1	<0.01	0	-----	1.38
Aug 2005	375,380,230	5	0.79	8	0.14	0	-----	2	0.06	5	0.01	1	0.01	0	-----	1.10
Sep 2005	20,836,490	5	0.60	7	0.03	0	-----	1	0.16	5	0.16	1	0.06	0	-----	1.74
Jun 2006	2,880,967,056	8	0.74	13	0.25	1	<0.01	1	<0.01	1	<0.01	1	<0.01	0	-----	0.98
Jul 2006	404,261,840	3	0.87	6	0.03	1	0.02	1	0.03	2	0.03	1	0.02	0	-----	0.70
Aug 2006	116,503,830	7	0.22	10	0.28	1	<0.01	1	0.14	5	0.31	2	0.04	1	<0.01	2.38
Sep 2006	121,255,178	6	0.52	12	0.25	0	-----	1	0.06	4	0.06	1	0.05	2	0.05	2.23
Jun 2007	1,767,149,650	10	0.93	10	0.06	1	<0.01	1	0.01	2	<0.01	1	<0.01	0	-----	0.55
Jul 2007	301,855,009	8	0.53	5	0.06	1	<0.01	1	0.06	2	0.11	1	0.22	1	0.02	1.55
Aug 2007	144,618,019	6	0.12	9	0.18	1	0.19	1	0.11	4	0.08	1	0.26	2	0.06	2.21
Sep 2007	231,862,268	5	0.74	14	0.13	0	-----	2	0.04	5	0.04	1	0.02	1	0.03	2.16
May 2008	1,111,689,197	15	0.99	1	<0.01	2	<0.01	1	0.01	0	-----	1	<0.01	0	-----	0.98
Jun 2008	559,678,249	8	0.99	5	<0.01	0	-----	1	0.01	1	<0.01	0	-----	0	-----	1.10
Jul 2008	142,699	2	0.61	7	0.12	1	0.01	1	0.12	2	0.01	1	0.13	0	-----	1.60
Aug 2008	119,345,010	6	0.87	1	0.01	2	0.02	1	0.04	2	0.05	1	0.01	0	-----	1.49
Sep 2008	369,704,260	5	0.60	9	0.08	0	-----	2	0.23	2	0.01	3	0.07	1	0.01	2.00
May 2009	1,821,391,059	13	0.20	5	0.19	1	<0.01	2	0.61	0	-----	1	<0.01	1	<0.01	1.48
Jun 2009	607,946,995	13	0.48	5	0.03	1	0.03	2	0.45	0	-----	0	-----	1	<0.01	1.68
Jul 2009	1,161,855,462	11	0.89	7	0.08	1	<0.01	2	0.03	1	<0.01	0	-----	0	<0.01	1.43
Aug 2009	172,666,483	3	0.18	7	0.13	0	-----	1	0.43	3	0.03	1	<0.01	0	-----	1.61
Sep 2009	1,256,060,787	7	0.68	12	0.16	0	-----	2	0.09	5	0.07	1	<0.01	0	-----	1.81
Mean*	**621,306,291**	**6.9**	**0.62**	**7.0**	**0.12**	**0.7**	**0.13**	**1.4**	**0.17**	**2.5**	**0.08**	**1.0**	**0.08**	**0.5**	**0.03**	**1.49**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 177. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Oahe at site OAHLK1196DW during the 5-year period 2005 through 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2005	120,198,449	6	0.96	2	0.02	0	-----	2	0.01	2	<0.01	0	-----	0	-----	1.63
Jul 2005	630,374,805	8	0.32	12	0.14	0	-----	2	0.31	7	0.20	1	0.04	0	-----	2.24
Aug 2005	166,745,682	5	0.58	2	0.11	0	-----	2	0.26	1	0.05	0	-----	0	-----	1.83
Sep 2005	22,057,409	6	0.88	3	0.03	0	-----	1	0.09	3	<0.01	0	-----	0	-----	1.52
Jun 2006	609,612,839	6	0.98	7	0.01	0	-----	1	<0.01	2	<0.01	1	<0.01	0	-----	0.97
Jul 2006	968,250,327	10	0.98	4	<0.01	1	<0.01	1	<0.01	4	<0.01	1	0.01	1	<0.01	1.43
Aug 2006	2,060,734,486	13	0.95	6	0.02	0	-----	1	0.02	3	<0.01	2	0.01	1	<0.01	1.81
Sep 2006	852,699,287	13	0.95	8	0.03	0	-----	1	0.01	2	<0.01	1	<0.01	1	<0.01	1.82
Jun 2007	1,819,909,690	10	0.91	10	0.07	1	<0.01	1	0.01	2	0.01	0	-----	0	-----	0.67
Jul 2007	800,167,337	10	0.65	8	0.02	0	-----	1	0.04	1	0.15	2	0.15	0	-----	1.49
Aug 2007	1,497,597,364	8	0.91	8	0.02	1	<0.01	0	-----	1	0.02	1	0.03	3	0.01	1.65
Sep 2007	887,246,429	9	0.94	8	0.03	0	-----	1	0.01	3	<0.01	1	0.02	2	<0.01	0.91
May 2008	536,864,521	11	0.98	2	<0.01	2	0.01	1	0.01	1	<0.01	0	-----	1	<0.01	1.72
Jun 2008	591,651,492	11	0.95	8	<0.01	1	<0.01	1	0.04	0	-----	0	-----	1	<0.01	1.52
Jul 2008	249,695	3	0.40	6	0.09	0	-----	1	0.42	3	0.01	2	0.08	0	-----	1.35
Aug 2008	213,733,459	9	0.72	8	0.01	3	0.01	1	0.20	6	0.06	2	<0.01	0	-----	1.75
Sep 2008	172,938,871	7	0.46	7	0.10	1	<0.01	2	0.34	4	0.08	2	0.03	1	<0.01	1.81
May 2009	129,008,232	11	0.43	6	0.09	1	<0.01	2	0.43	0	-----	1	0.02	1	0.02	2.18
Jun 2009	573,225,916	7	0.79	6	0.05	1	<0.01	2	0.16	0	-----	0	-----	0	-----	0.86
Jul 2009	252,438,172	5	0.85	5	0.09	1	0.03	1	0.02	2	0.01	0	-----	0	-----	1.44
Aug 2009	5,153,283,533	7	0.49	8	0.01	2	<0.01	2	0.02	4	<0.01	1	0.47	0	-----	1.35
Sep 2009	1,001,344,873	11	0.57	11	0.13	1	<0.01	2	0.12	6	0.17	0	-----	0	-----	2.40
Mean*	**866,378,767**	**8.5**	**0.76**	**6.6**	**0.05**	**0.7**	**<0.01**	**1.3**	**0.12**	**2.6**	**0.04**	**0.8**	**0.07**	**0.5**	**<0.01**	**1.56**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 178. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Oahe at site OAHLK1256DW during the 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2009	143,466,054	7	0.10	10	0.04	1	0.08	1	0.48	5	0.30	0	-----	0	-----	1.76
Jul 2009	445,769,814	11	0.82	1	0.06	1	0.06	1	0.03	3	0.03	1	<0.01	1	<0.01	1.81
Aug 2009	2,763,297,459	13	0.86	10	0.02	2	0.02	2	0.08	3	<0.01	1	<0.01	0	-----	1.53
Sep 2009	2,836,920,584	18	0.84	5	<0.01	2	0.03	2	0.11	4	0.01	2	0.01	2	<0.01	1.85
Mean*	**1,547,363,478**	**12.3**	**066**	**6.5**	**0.03**	**1.5**	**0.05**	**1.5**	**0.18**	**3.8**	**0.9**	**1.0**	**<0.01**	**0.8**	**<0.01**	**1.74**

* Mean percent composition represents the mean when taxa of that division are present.

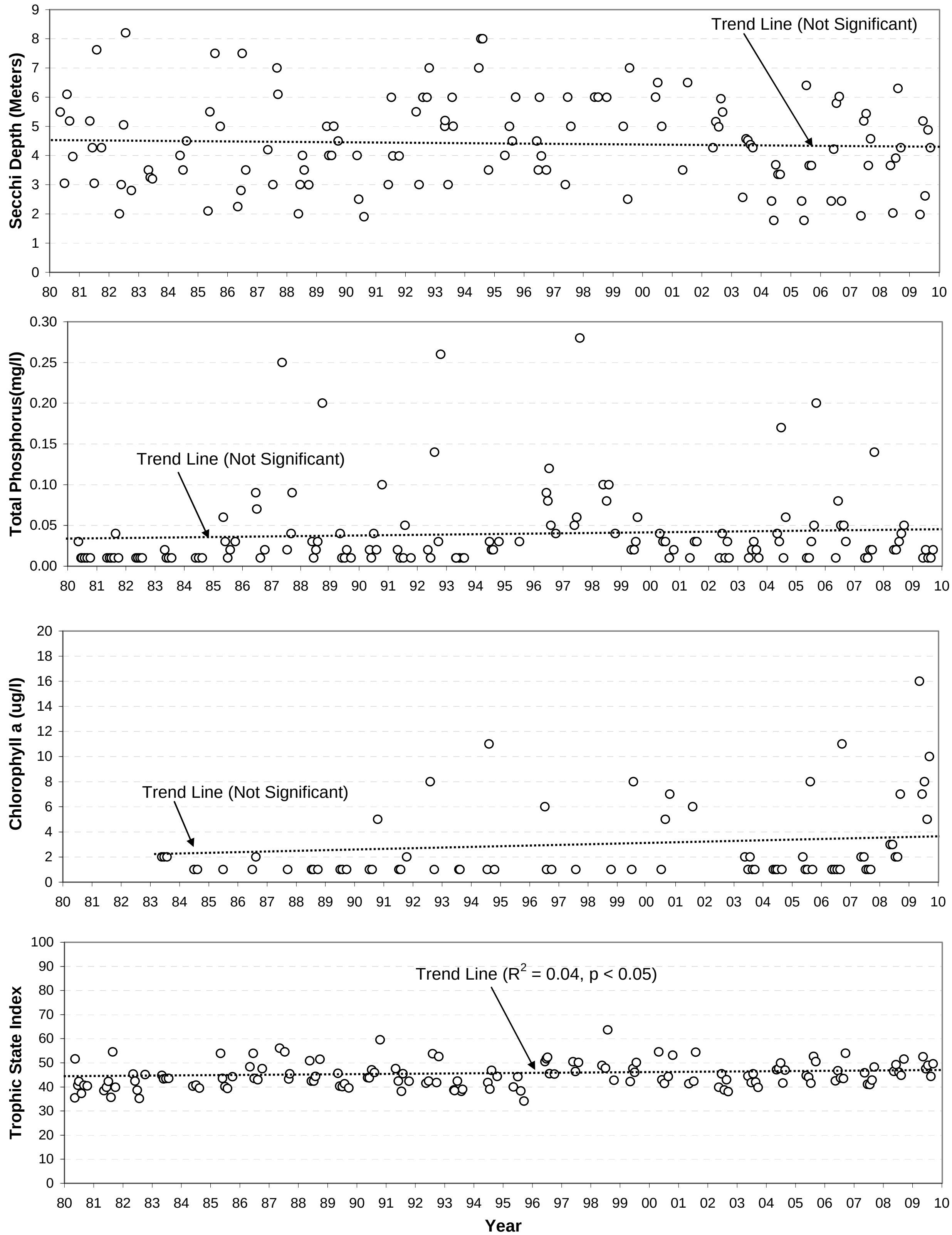


Plate 179. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Lake Oahe at the near-dam, ambient site (i.e., site OAHLK1073A) over the 29-year period of 1980 through 2009.

Plate 180. Summary of monthly (April through September) water quality conditions monitored in the Missouri River at Bismarck, North Dakota at monitoring site OAHNFMORR1 during the 5-year period 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	27	15,764	15,500	10,564	26,800	-----	-----	-----
Water Temperature (°C)	0.1	26	18.1	18.4	7.8	25.5	29.4(1,2)	0	0%
Dissolved Oxygen (mg/l)	0.1	26	9.4	9.3	8.1	11.6	5(1,3)	0	0%
Dissolved Oxygen (% Sat.)	0.1	26	102.4	102.3	93.6	109.7	-----	-----	-----
pH (S.U.)	0.1	26	8.3	8.3	7.9	8.7	7.0(1,3), 9.0(1,2)	0	0%
Specific Conductance (umho/cm)	1	26	618	620	561	659	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	26	377	355	282	531	-----	-----	-----
Turbidity (NTU)	1	26	17	6	n.d.	127	-----	-----	-----
Alkalinity, Total (mg/l)	7	27	159	158	140	185	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	26	2.9	3.1	n.d.	5.0	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	23	11	11	2	24	-----	-----	-----
Chloride, Dissolved (mg/l)	1	22	10	10	8	11	100(1,2)	0	0%
Dissolved Solids, Total (mg/l)	5	26	439	420	390	620	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	27	-----	0.03	n.d.	0.11	4.7 (1,2,4), 1.1 (1,4,5)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	27	0.3	0.3	n.d.	0.9	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	26	0.07	0.08	n.d.	0.14	1.0(1,2)	0	0%
Nitrogen, Total (mg/l)	0.1	25	0.4	0.4	n.d.	1.0	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	27	-----	n.d.	n.d.	0.17	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	27	0.07	0.04	n.d.	0.29	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	27	-----	n.d.	n.d.	0.06	-----	-----	-----
Sulfate (mg/l)	1	26	163	165	141	190	250(1,2)	0	0%
Suspended Solids, Total (mg/l)	4	27	18	18	n.d.	64	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for Class 1 streams.
- (2) Daily maximum criterion (monitoring results directly comparable to criterion).
- (3) Daily minimum criterion (monitoring results directly comparable to criterion).
- (4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (5) 30-day average criterion (monitoring results not directly comparable to criterion).

Plate 181. Summary of annual metals and pesticide levels monitored in the Missouri River at Bismarck, North Dakota at monitoring site OAHNFMORR1 during the 5-year period 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Aluminum, Total (ug/l)	25	3	310	360	200	370	750[6]	0	0%
Antimony, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Antimony, Total (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	5.6[8]	0	0%
Arsenic, Dissolved (ug/l)	1	5	-----	n.d.	n.d.	1	-----	-----	-----
Arsenic, Total (ug/l)	1	3	-----	1	n.d.	2	340[1], 150[2], 10[3]	0	0%
Barium, Dissolved (ug/l)	5	3	57	55	53	64	-----	-----	-----
Barium, Total (ug/l)	5	3	63	60	60	70	1,000[8]	0	0%
Beryllium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Beryllium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	4[8]	0	0%
Cadmium, Dissolved (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Cadmium, Total (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	4.5[6], 0.47[7], 5[8]	0	0%
Chromium, Dissolved (ug/l)	10	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Chromium, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	3,298[6], 158[7], 100[8]	0	0%
Copper, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Copper, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	28[6], 18[7], 1,000[8]	0	0%
Hardness, Total (mg/l)	0.4	4	206	209	179	225	-----	-----	-----
Iron, Dissolved (ug/l)	40	16[A]	-----	n.d.	n.d.	40	-----	-----	-----
Iron, Total (ug/l)	40	17[A]	493	430	190	1,614	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Lead, Total (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	209[6], 8.1[7], 15[8]	0	0%
Manganese, Dissolved (ug/l)	2	17[A]	-----	3	n.d.	10	-----	-----	-----
Manganese, Total (ug/l)	2	17[A]	18	16	10	41	-----	-----	-----
Mercury, Dissolved (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Mercury, Total (ug/l)	0.02	4	-----	n.d.	n.d.	n.d.	1.7[6], 0.012[7], 0.05[8]	0, b.d., 0	0%
Nickel, Dissolved (ug/l)	10	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Nickel, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	875[6], 97[7], 100[8]	0	0%
Selenium, Total (ug/l)	1	2	-----	n.d.	n.d.	n.d.	20[6], 5[7], 50[8]	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Silver, Total (ug/l)	1	3	-----	n.d.	n.d.	n.d.	14[6]	0	0%
Thallium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Total (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	0.24[7]	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	4	-----	n.d.	n.d.	30	-----	-----	-----
Zinc, Total (ug/l)	10	3	-----	n.d.	n.d.	50	224[6,7], 7,400[8]	0	0%
Pesticide Scan (ug/l)[D]	0.05	3	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Results for iron (dissolved and total) and manganese (dissolved and total) include some monthly samples.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for Class 1 streams.
(2) Daily maximum criterion (monitoring results directly comparable to criterion).
(3) Daily minimum criterion (monitoring results directly comparable to criterion).
(4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(5) 30-day average criterion (monitoring results not directly comparable to criterion).
(6) Acute criterion for aquatic life.
(7) Chronic criterion for aquatic life.
(8) Human health criterion for surface waters.

Note: Some of North Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

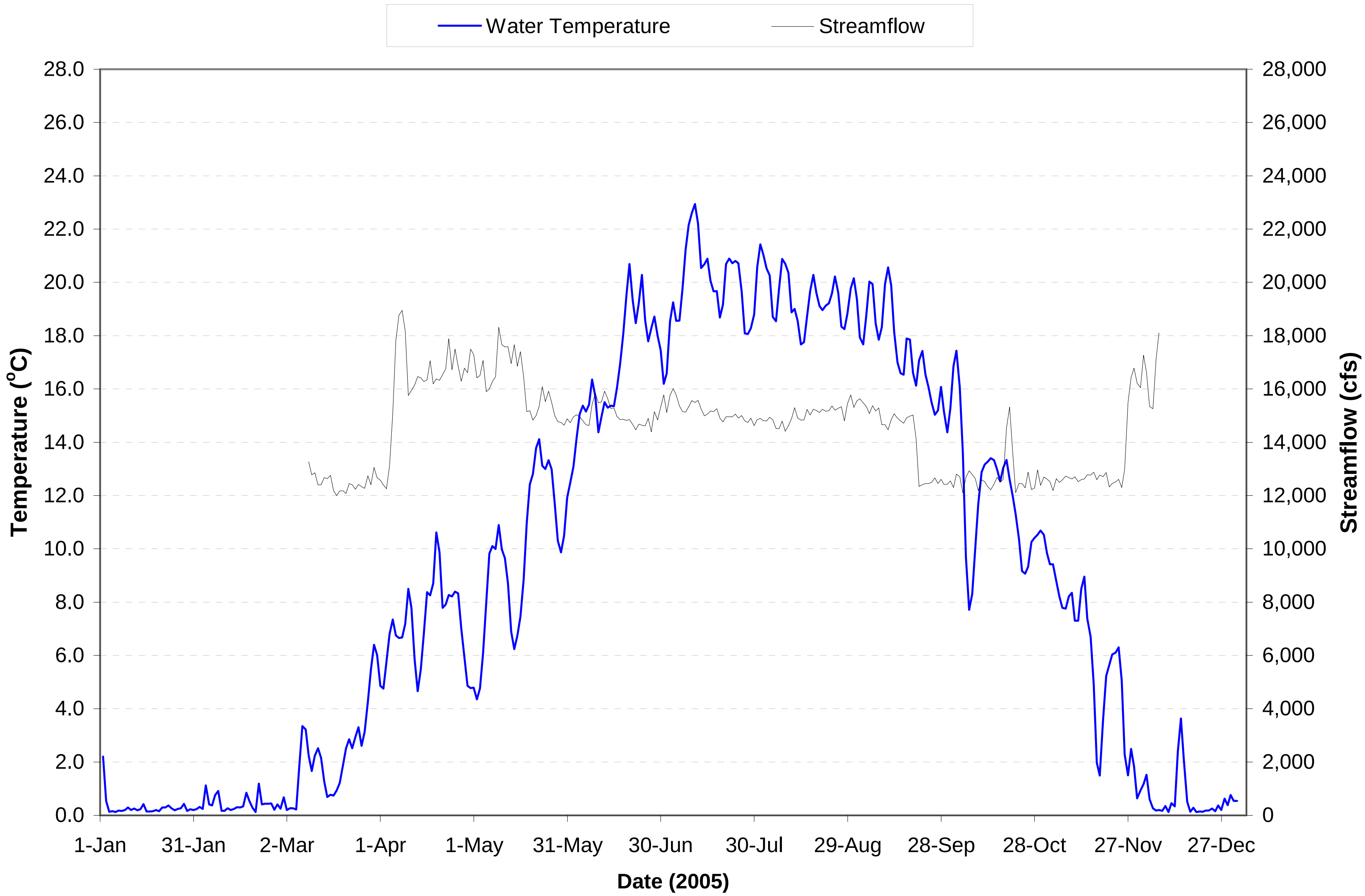


Plate 182. Mean daily water temperature and discharge of the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) for 2005. Mean daily temperatures and discharges based on hourly measurements recorded on the Missouri River at Bismarck, North Dakota (USGS gaging station 06342500).

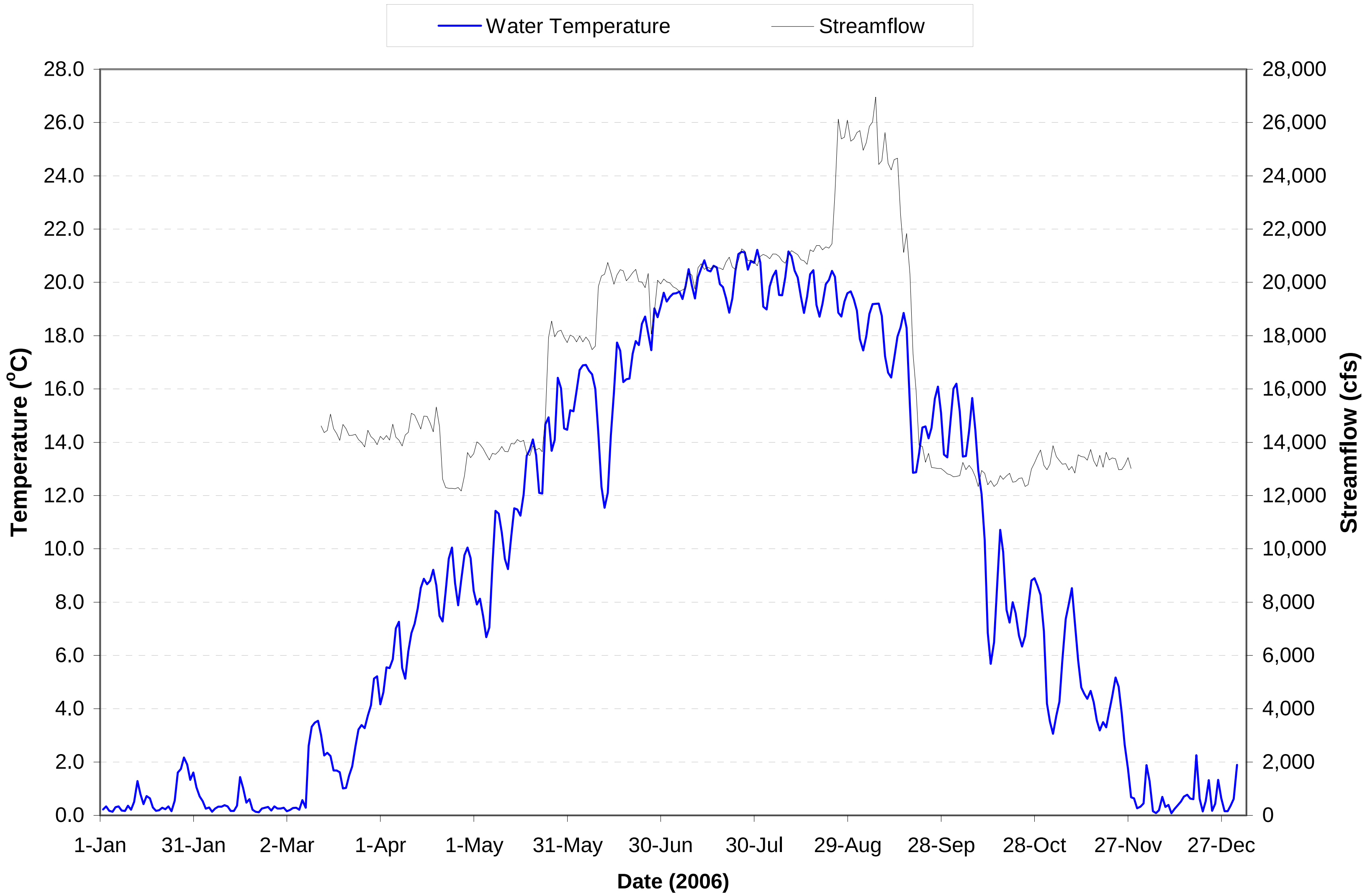


Plate 183. Mean daily water temperature and discharge of the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) for 2006. Mean daily temperatures and discharges based on hourly measurements recorded on the Missouri River at Bismarck, North Dakota (USGS gaging station 06342500).

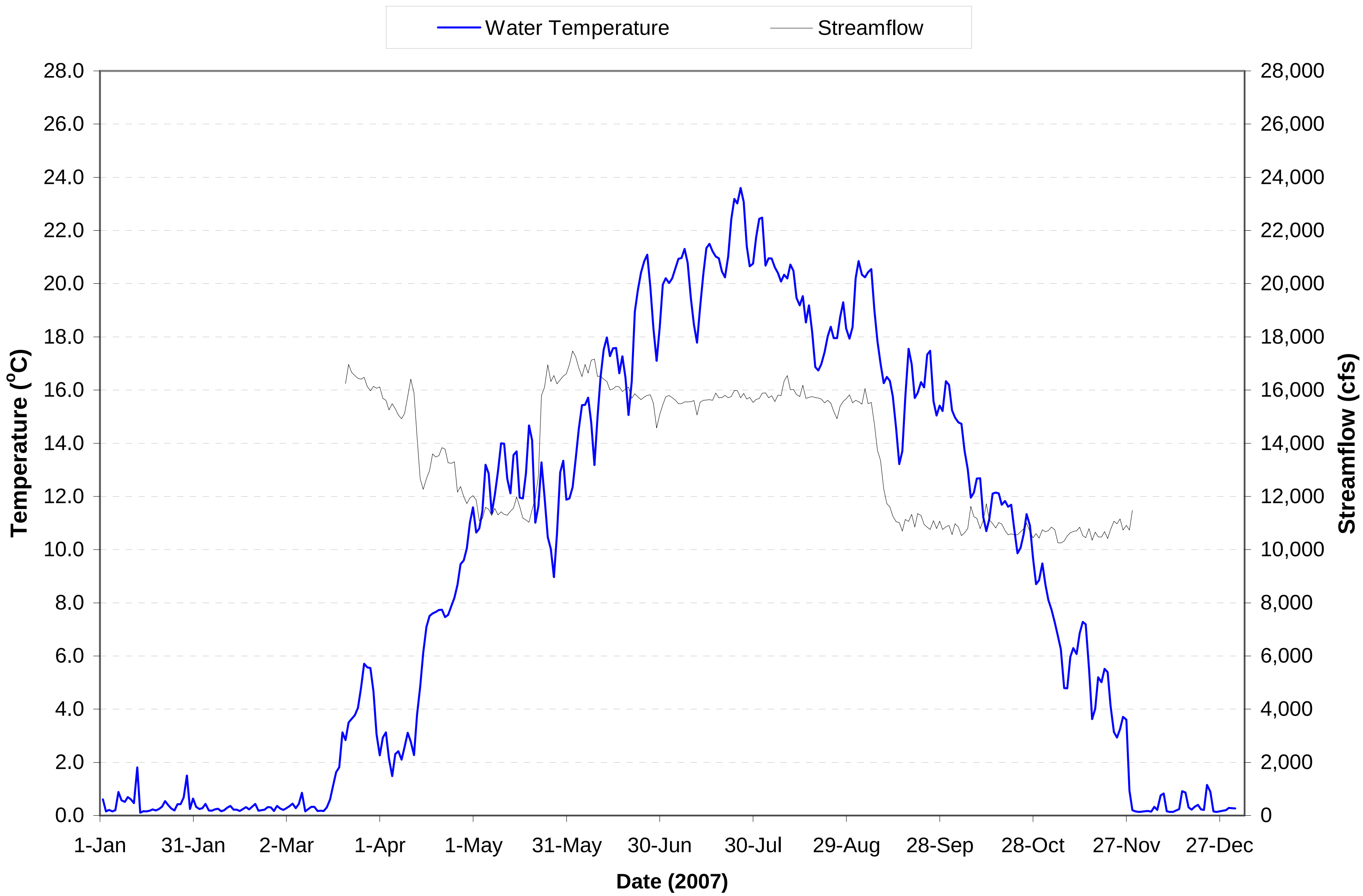


Plate 184. Mean daily water temperature and discharge of the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) for 2007. Mean daily temperatures and discharges based on hourly measurements recorded on the Missouri River at Bismarck, North Dakota (USGS gaging station 06342500).

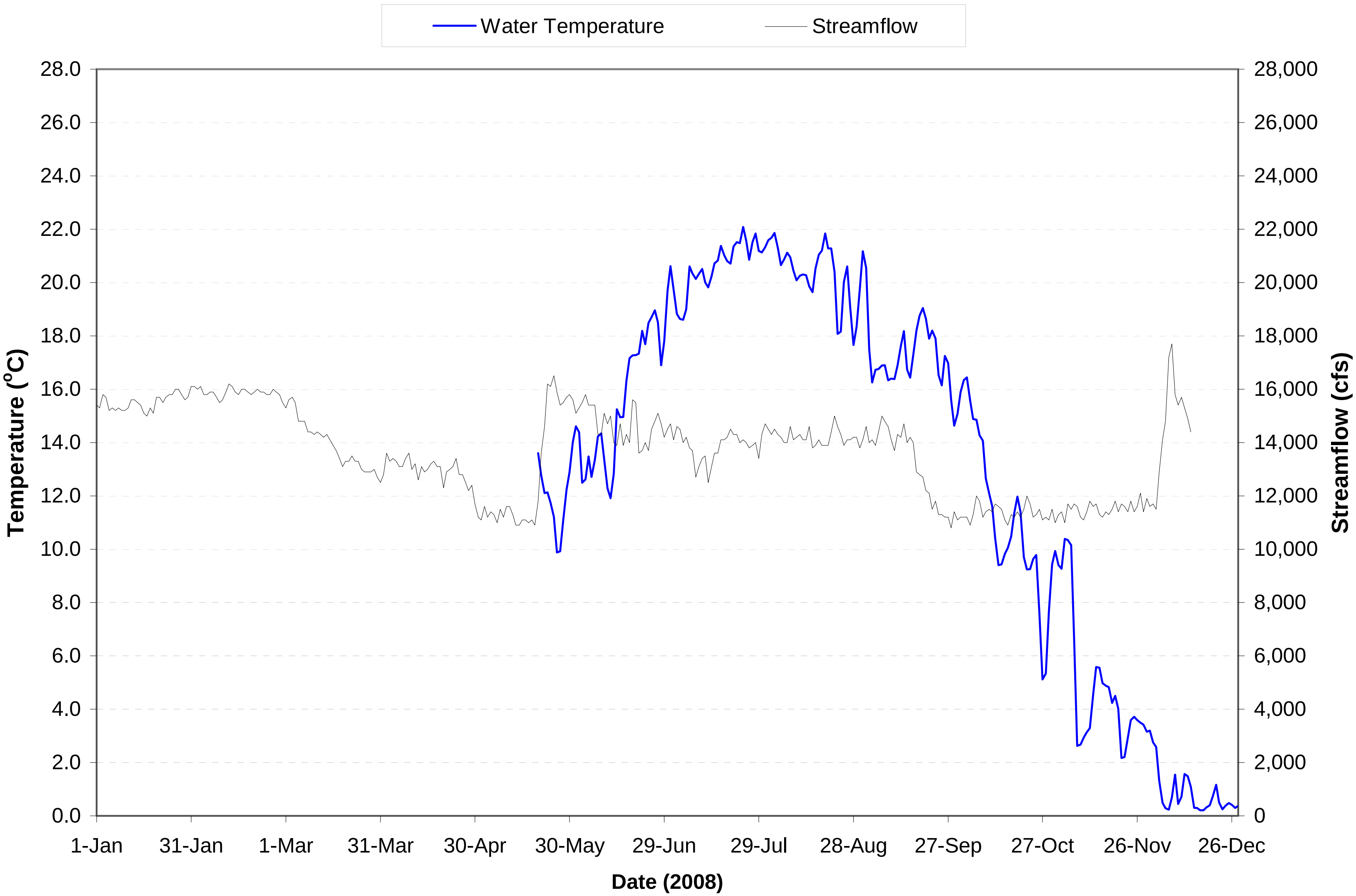


Plate 185. Mean daily water temperature and discharge of the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) for 2008. Mean daily temperatures and discharges based on hourly measurements recorded on the Missouri River at Bismarck, North Dakota (USGS gaging station 06342500).

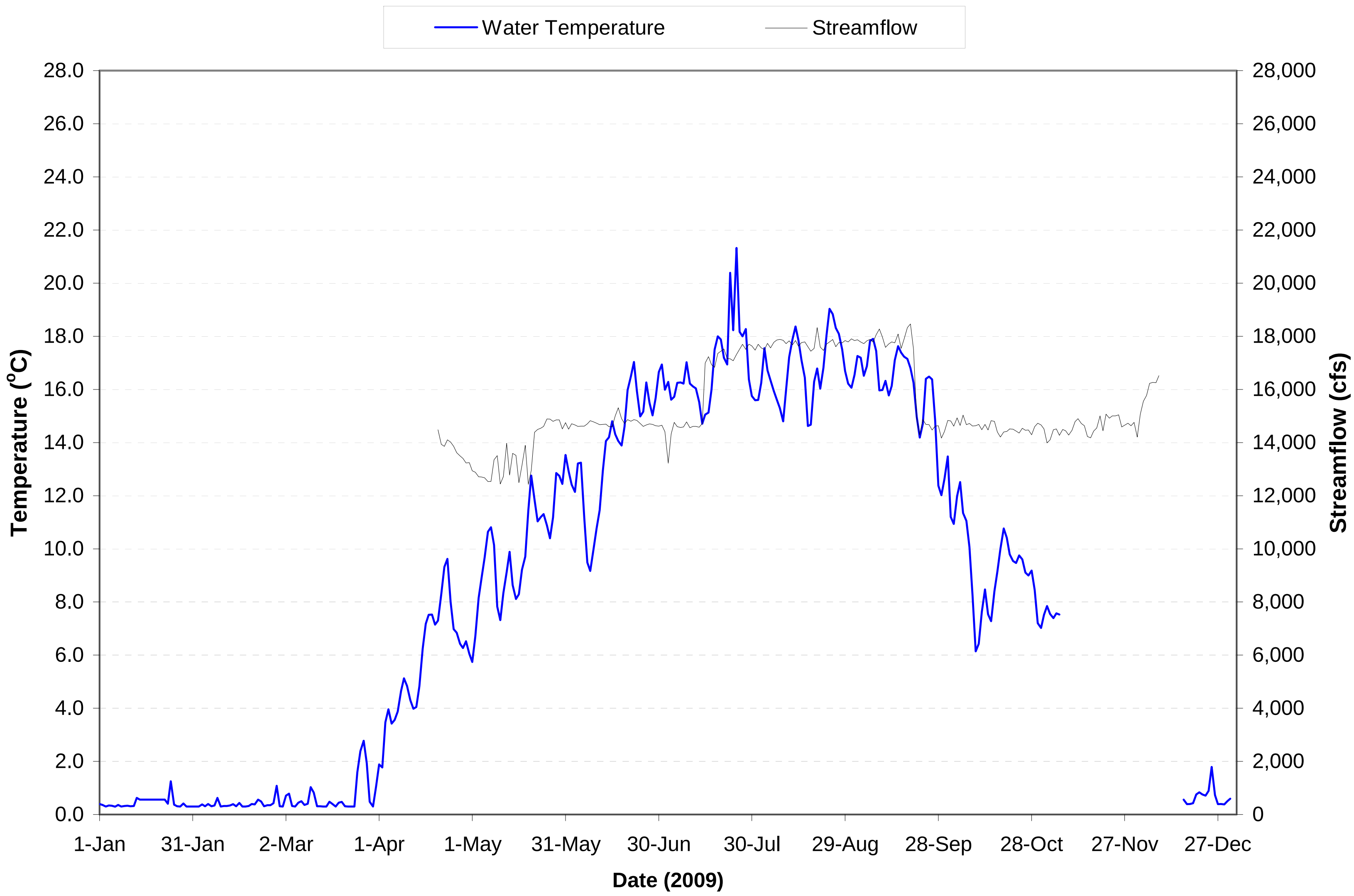


Plate 186. Mean daily water temperature and discharge of the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) for 2009. Mean daily temperatures and discharges based on hourly measurements recorded on the Missouri River at Bismarck, North Dakota (USGS gaging station 06342500).

Plate 187. Summary of monthly water quality conditions monitored on water discharged through Oahe Dam (i.e., site OAHPP1) during the 5-year period of 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[(A)]	No. of Obs.	Mean[(B)]	Median	Min.	Max.	State WQS Criteria[(C)]	No. of WQS Exceedances	Percent WQS Exceedance
Dam Discharge (cfs)	1	52	20,578	20,997	0	51,658	-----	-----	-----
Water Temperature (°C)	0.1	51	11.3	11.3	0.8	23.2	18.3[(1,5)]	12	24%
Dissolved Oxygen (mg/l)	0.1	51	10.3	10.2	7.1	15.0	5[(3,6)], 6[(1,6,8)], 7[(1,6,8)]	0	0%
Dissolved Oxygen (% Sat.)	0.1	51	95.6	96.2	72.3	112.1	-----	-----	-----
pH (S.U.)	0.1	41	8.2	8.3	7.3	8.6	6.5[(1,2,6)], 9.0[(1,2,5)], 9.5[(4,5)]	0	0%
Specific Conductance (umho/cm)	1	51	678	689	357	816	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	34	383	364	266	666	-----	-----	-----
Turbidity (NTU)	1	32	3	2	n.d.	19	-----	-----	-----
Alkalinity, Total (mg/l)	7	52	166	165	140	202	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	50	3.1	3.0	1.2	5.9	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	41	8	8	n.d.	19	-----	-----	-----
Chloride, Dissolved (mg/l)	1	38	11	11	6	22	175[(1,5)], 438[(2,5)] 100[(1,7)], 250[(2,7)]	0	0%
Dissolved Solids, Total (mg/l)	5	52	481	464	396	850	1,750[(2,5)], 3,500[(4,5)] 1,000[(2,7)], 2,000[(4,7)]	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	52	-----	n.d.	n.d.	0.31	3.1 [(1,5,9)], 1.4 [(1,7,9)]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	52	0.4	0.3	n.d.	1.8	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	52	-----	n.d.	n.d.	0.20	10[(2,5)]	0	0%
Nitrogen, Total (mg/l)	0.1	52	0.4	0.4	n.d.	1.9	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	43	-----	n.d.	n.d.	0.20	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	52	-----	0.02	n.d.	0.29	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	52	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	52	198	200	163	230	875[(2,5)], 500[(2,7)]	0	0%
Suspended Solids, Total (mg/l)	4	52	-----	n.d.	n.d.	91	53[(1,5)], 30[(1,7)]	1, 1	2%, 2%

n.d. = Not detected, b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

Plate 188. Summary of annual metals and pesticide levels monitored on water discharged through Oahe Dam (i.e., site OAHPP1) during the 5-year period of 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Aluminum, Total (ug/l)	25	3	89	80	78	110	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Antimony, Total (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	5.6(3)	0	0%
Arsenic, Dissolved (ug/l)	1	3	1	1	1	2	340(1), 150(2)	0, 0	0%, 0%
Arsenic, Total (ug/l)	1	3	1	1	n.d.	2	0.018(3)	b.d.	b.d.
Barium, Dissolved (ug/l)	5	3	42	42	41	43	-----	-----	-----
Barium, Total (ug/l)	5	3	46	45	43	50	-----	-----	-----
Beryllium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Beryllium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	4(3)	0	0%
Cadmium, Dissolved (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	4.4(1), 0.43(2)	0	0%
Cadmium, Total (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	5(3)	0	0%
Chromium, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	n.d.	1,103(1), 143(2)	0	0%
Chromium, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Copper, Dissolved (ug/l)	2	7	-----	2	n.d.	6	29(1), 18(2),	0	0%
Copper, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	1,300(3)	0	0%
Hardness, Total (mg/l)	0.4	4	224	224	209	240	-----	-----	-----
Iron, Dissolved (ug/l)	40	26(A)	-----	n.d.	n.d.	50	-----	-----	-----
Iron, Total (ug/l)	40	26(A)	109	60	n.d.	540	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	154(1), 6.0(2)	0	0%
Lead, Total (ug/l)	0.5	3	1.4	1.0	1.0	2.1	-----	-----	-----
Manganese, Dissolved (ug/l)	2	26(A)	-----	n.d.	n.d.	16	-----	-----	-----
Manganese, Total (ug/l)	2	26(A)	16	11	n.d.	66	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	6	-----	n.d.	n.d.	n.d.	1.4(1)	0	0%
Mercury, Total (ug/l)	0.05	6	-----	n.d.	n.d.	n.d.	0.77(2), 0.05(3)	0	0%
Nickel, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	n.d.	926(1), 103(2)	0	0%
Nickel, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	610(3)	0	0%
Selenium, Total (ug/l)	1	3	-----	1	n.d.	2	4.6(2), 170(3)	0	0%
Silver, Dissolved (ug/l)	1	7	-----	n.d.	n.d.	n.d.	13(1)	0	0%
Silver, Total (ug/l)	1	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Total (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	0.24(3)	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	11	232(1,2)	0	0%
Zinc, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	7,400(3)	0	0%
Pesticide Scan (ug/l)(D)	0.05	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected, b.d. = Criterion below detection limit.

(A) Results for iron (dissolved and total) and manganese (dissolved and total) include some monthly samples.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Acute (CMC) criterion for the protection of freshwater aquatic life.

(2) Chronic (CCC) criterion for the protection of freshwater aquatic life.

(3) Criterion for the protection of human health.

Note: Some of South Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

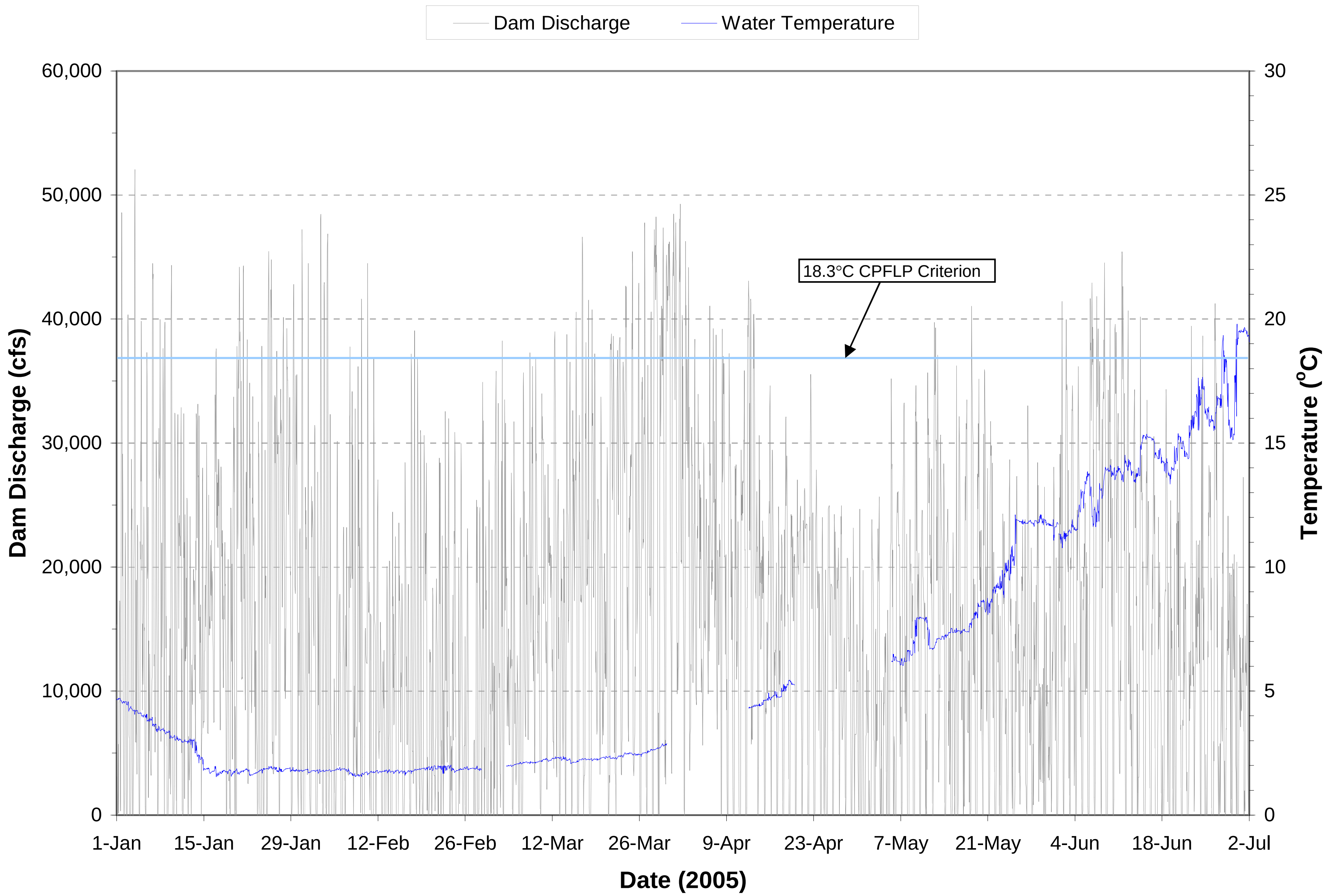


Plate 189. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2005.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

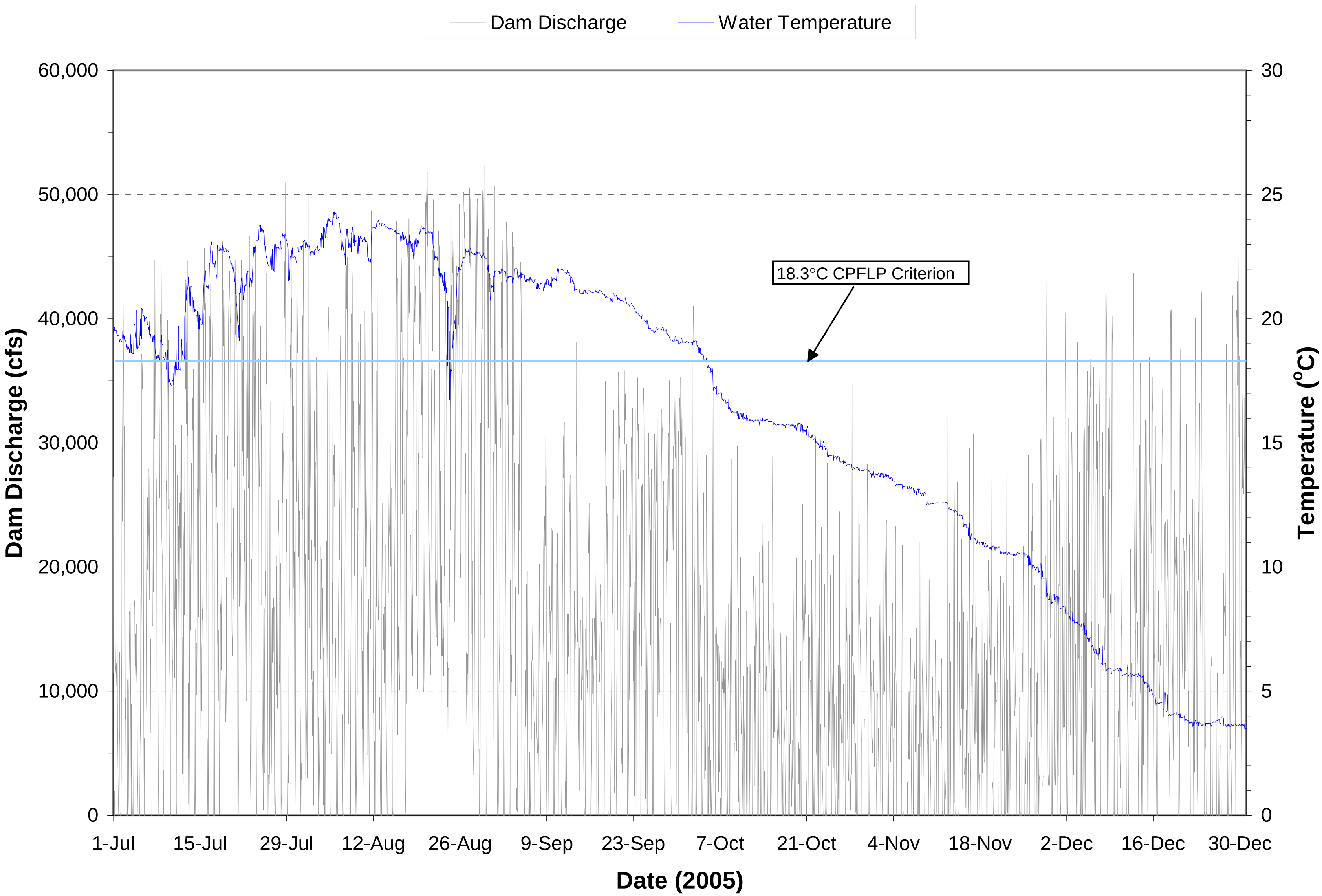


Plate 190. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2005.

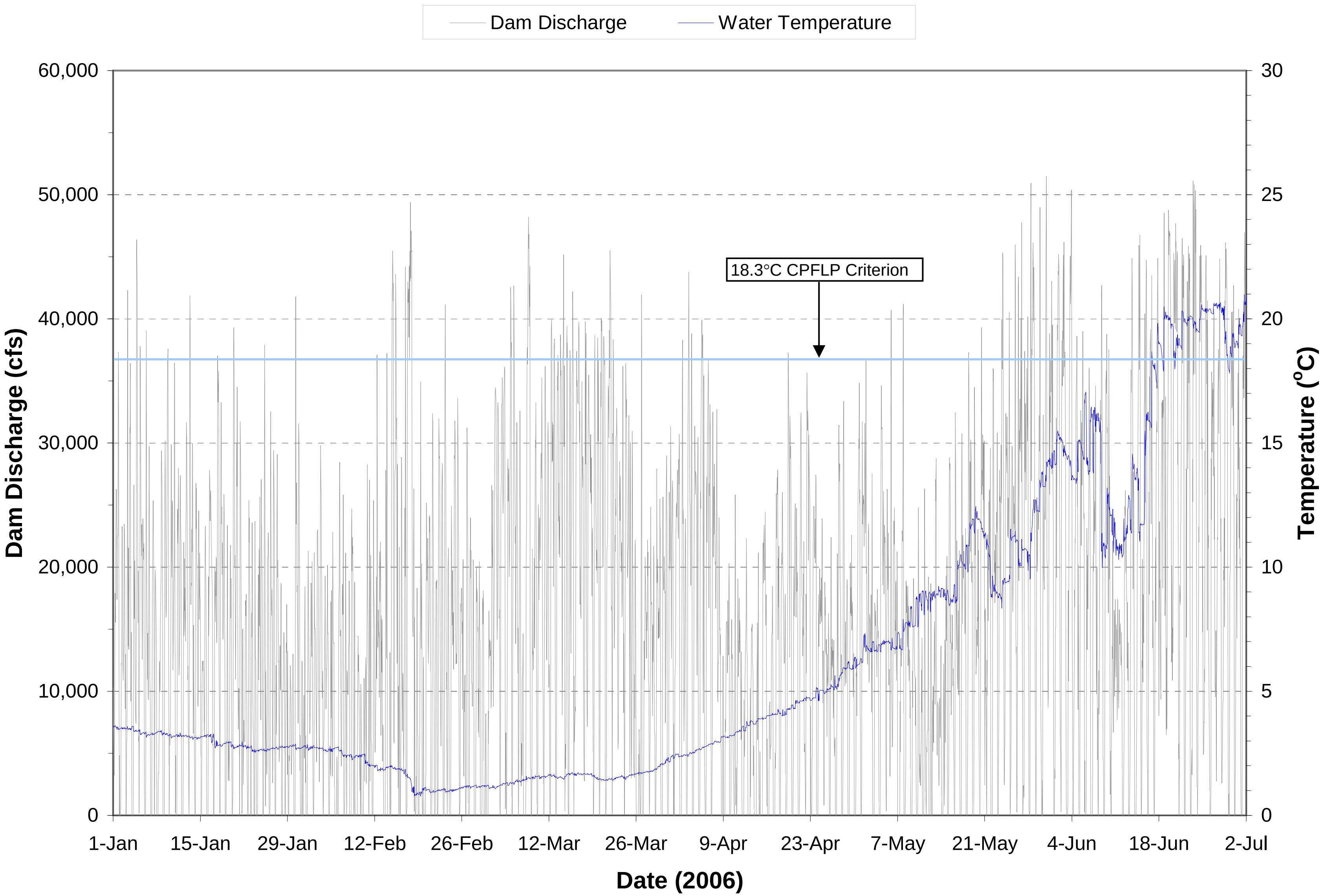


Plate 191. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2006.

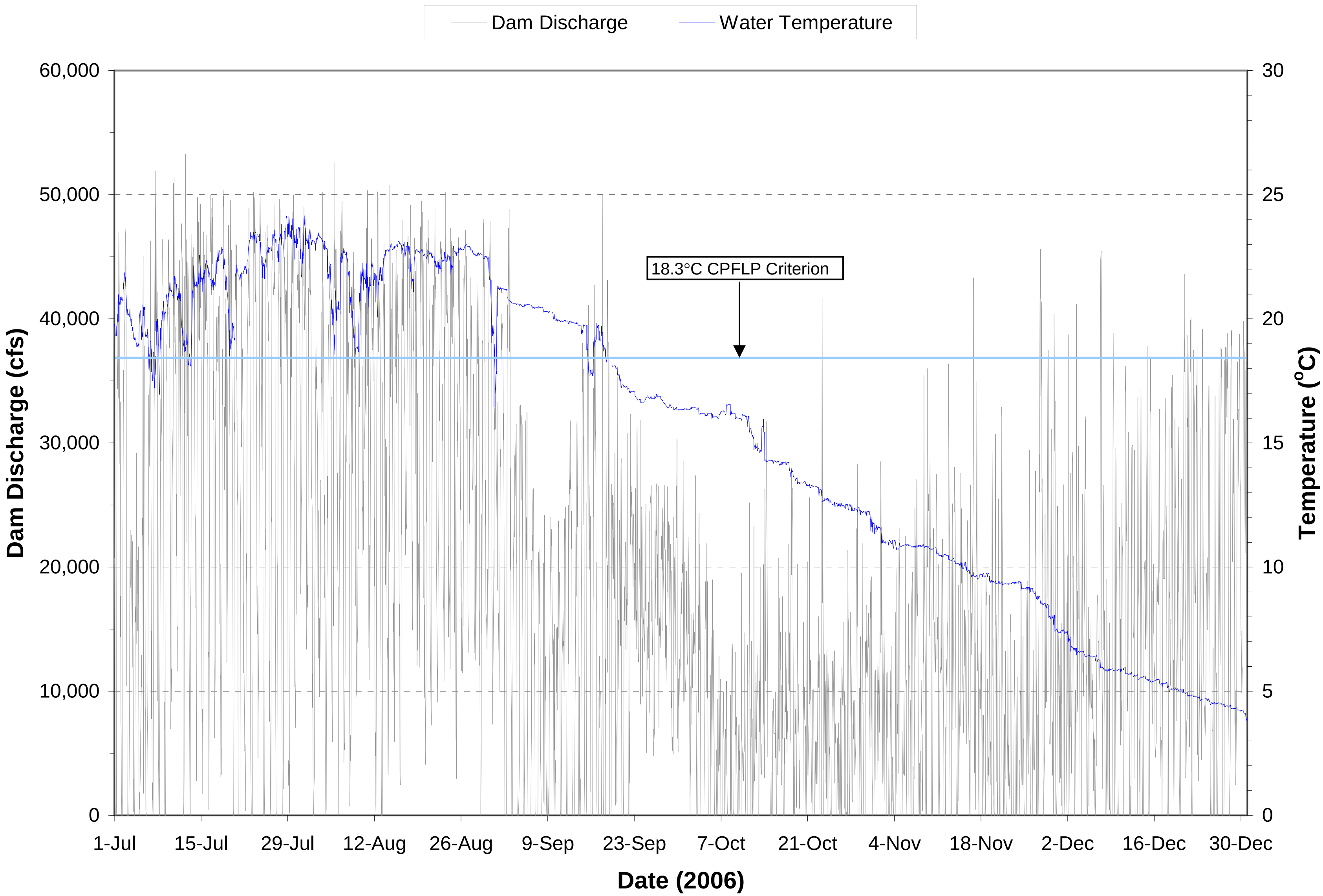


Plate 192. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2006.

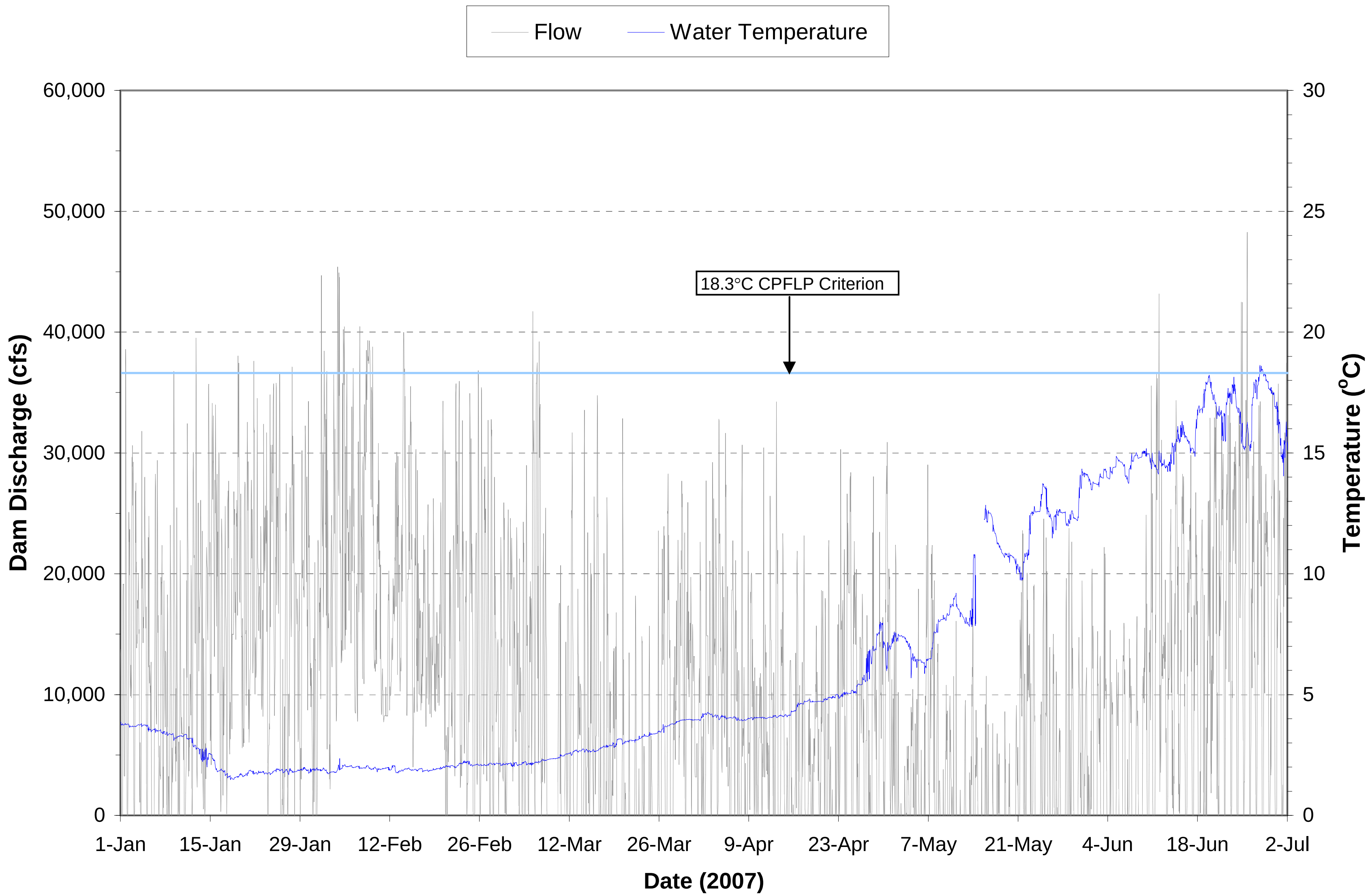


Plate 193. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2007.

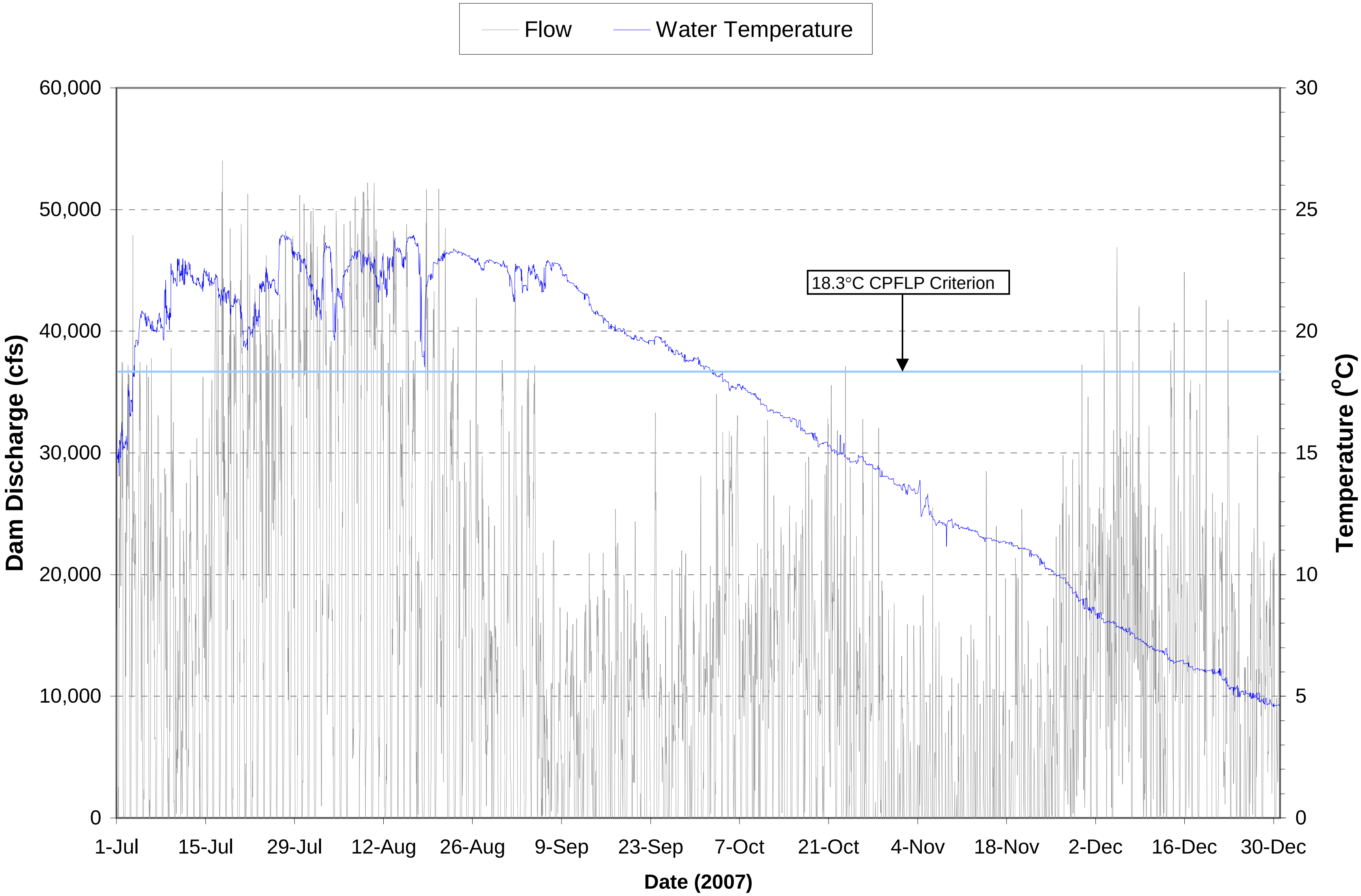


Plate 194. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2007.

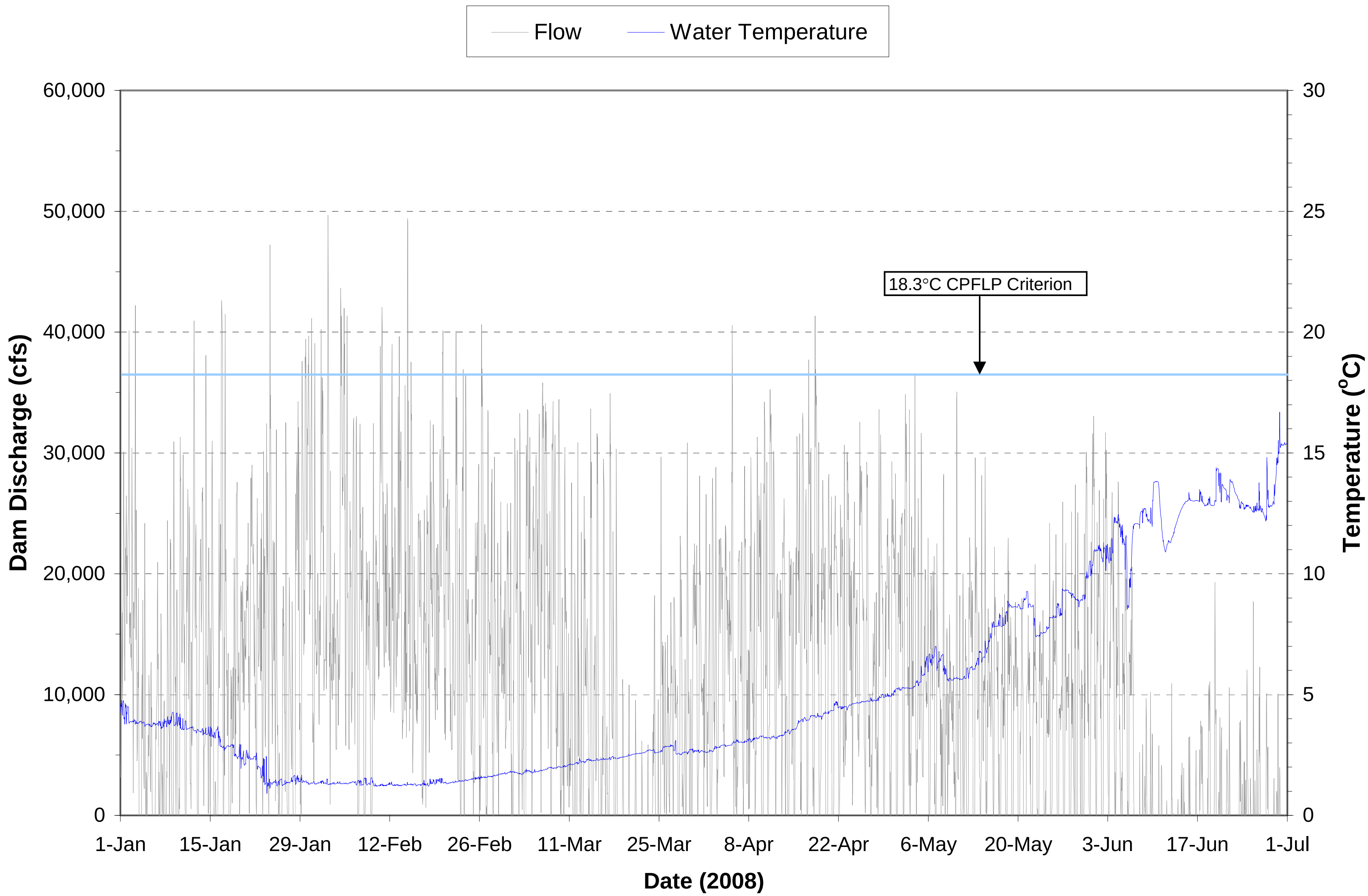


Plate 195. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2008.

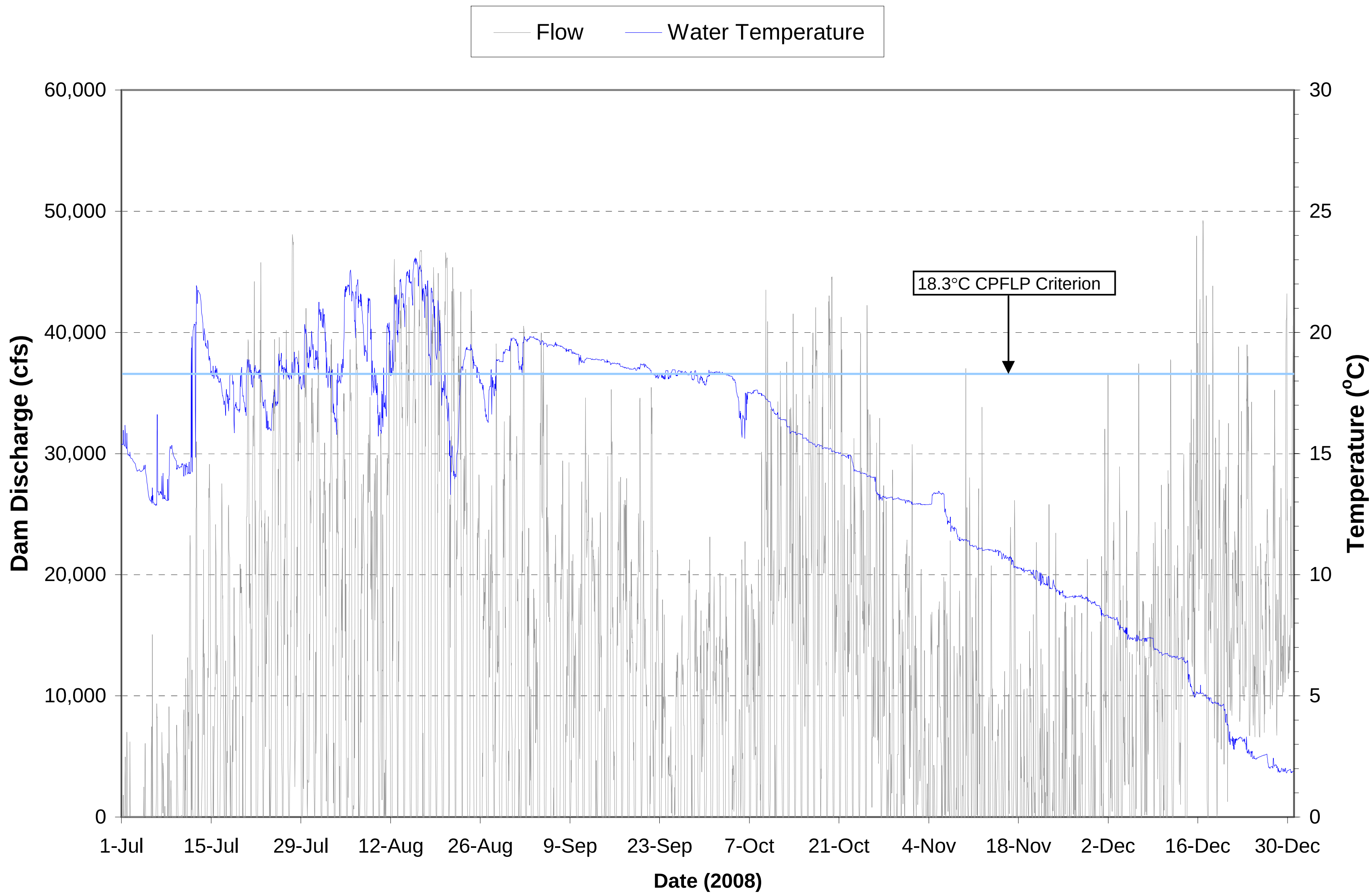


Plate 196. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2008.

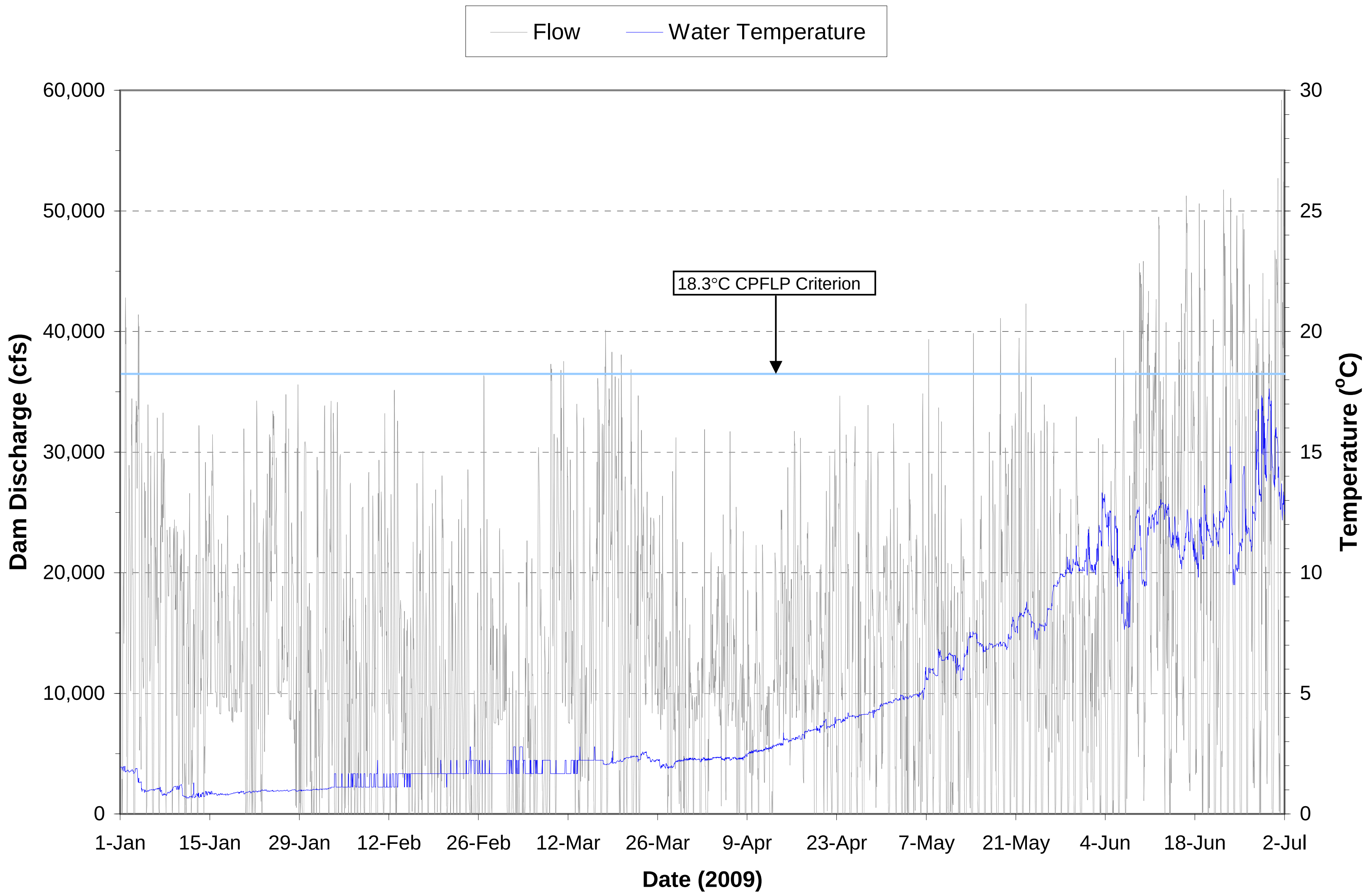


Plate 197. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2009.

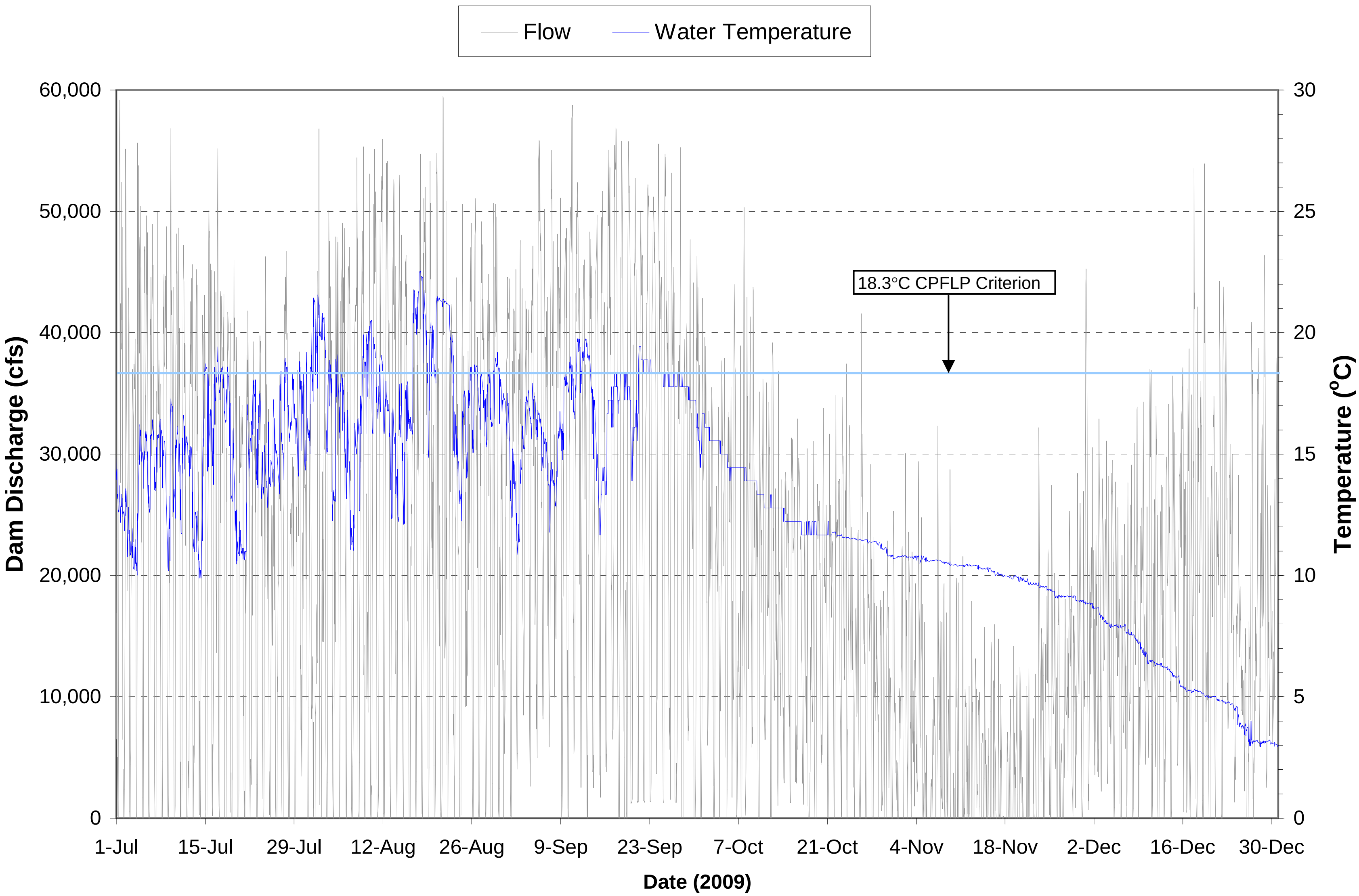


Plate 198. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2009.

Plate 199. Hourly discharge and dissolved oxygen monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2005.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

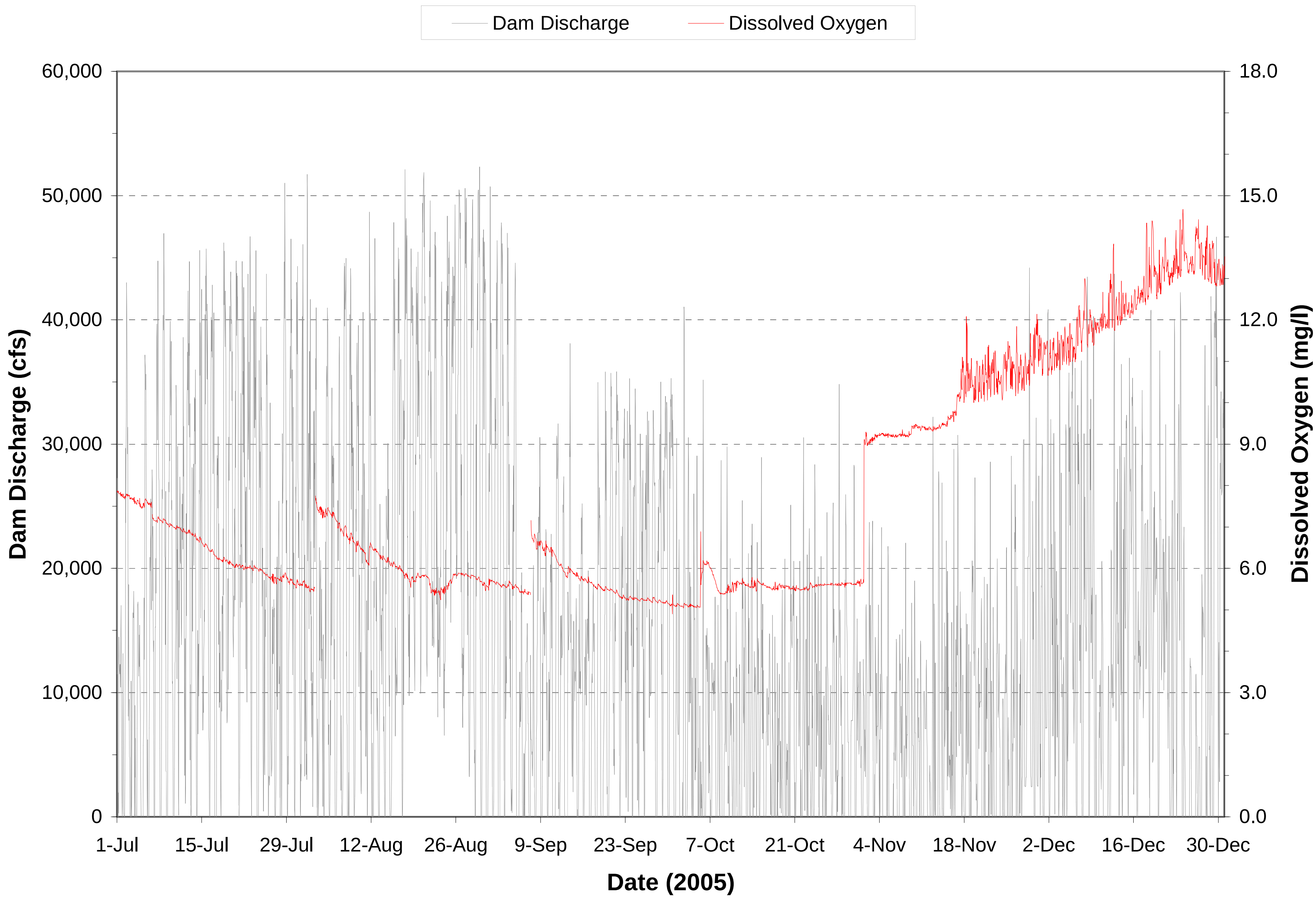


Plate 200. Hourly discharge and dissolved oxygen monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2005.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

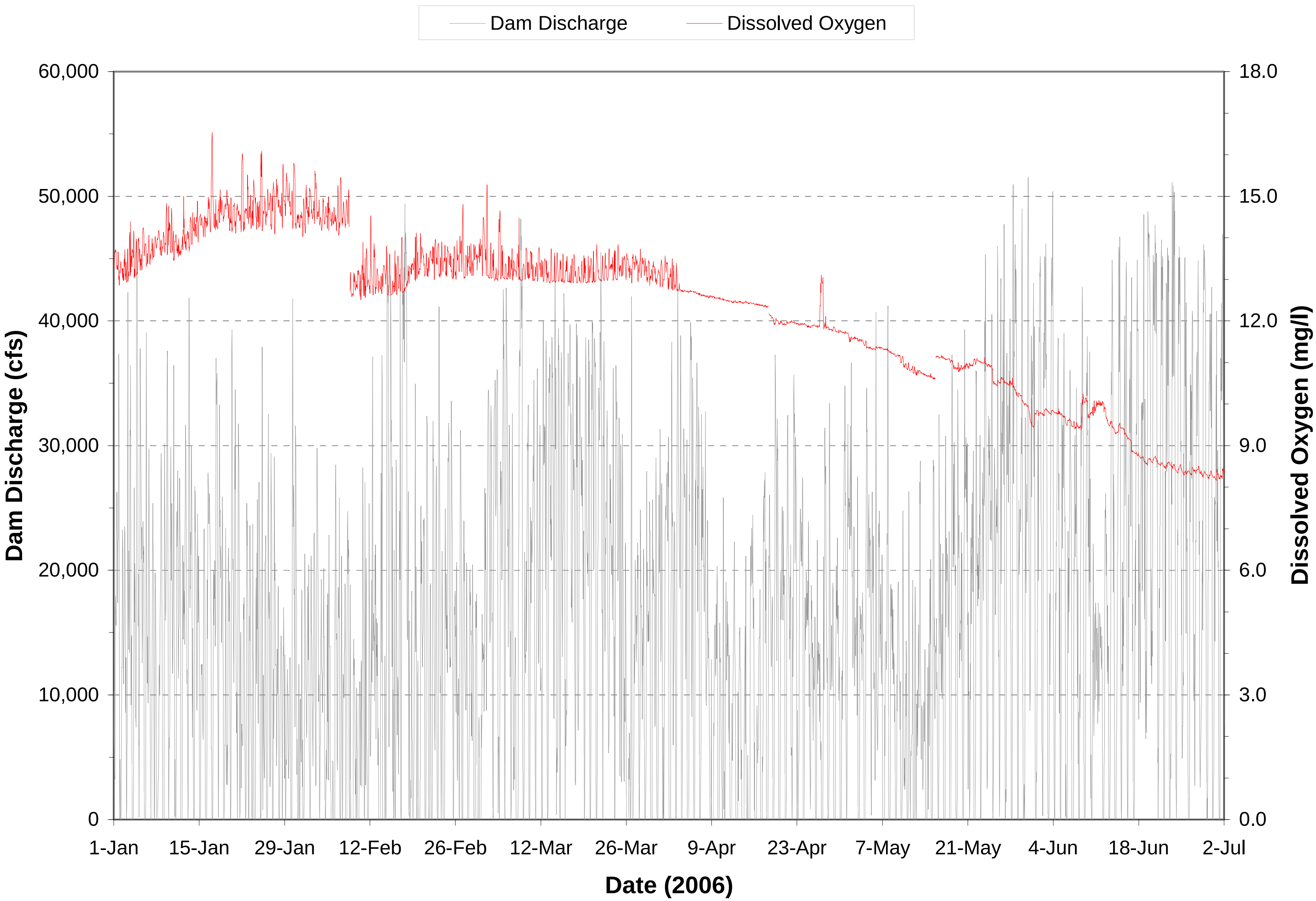


Plate 201. Hourly discharge and dissolved oxygen monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

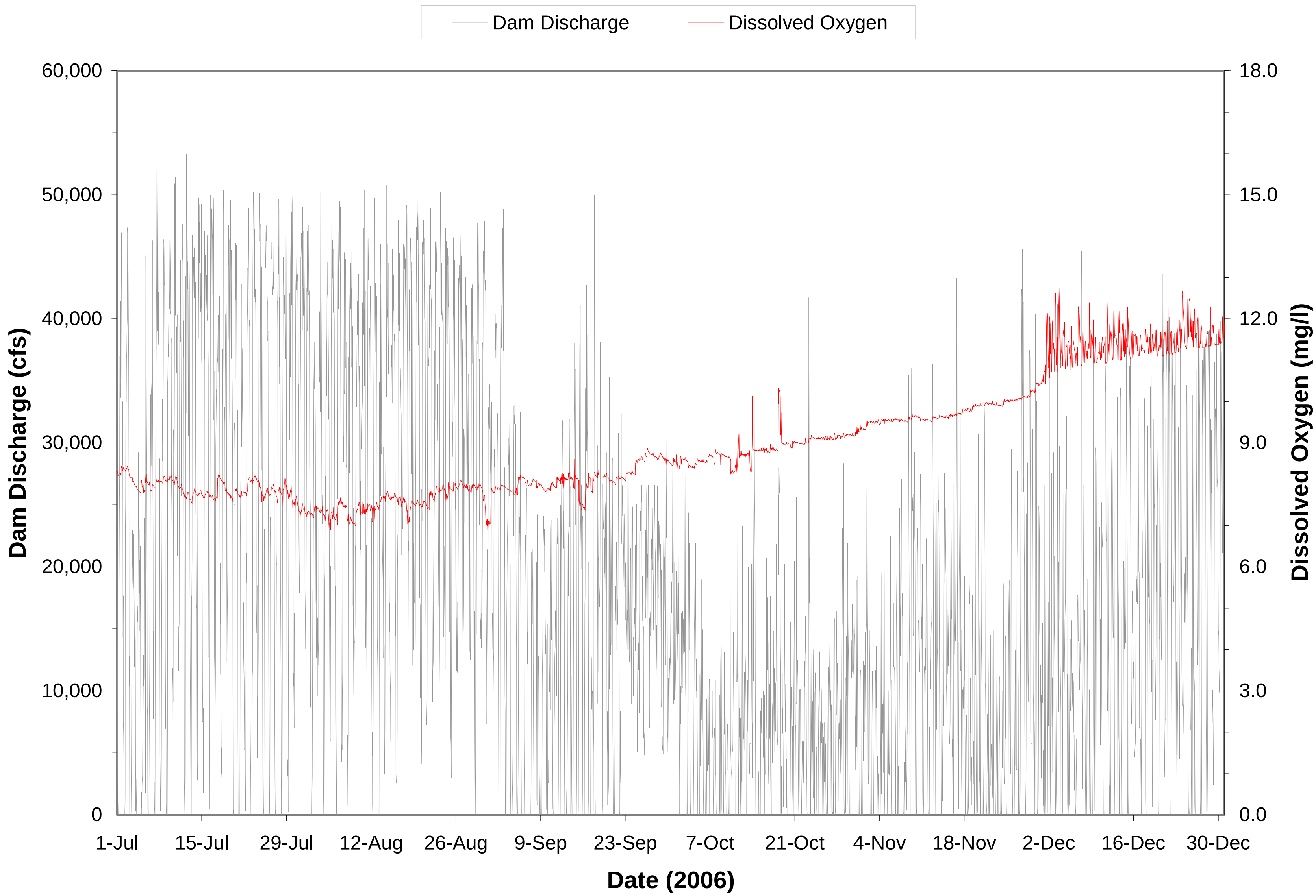


Plate 202. Hourly discharge and dissolved oxygen monitored at the Oahe Powerplant on water discharged through the dam during the period July through December 2006.

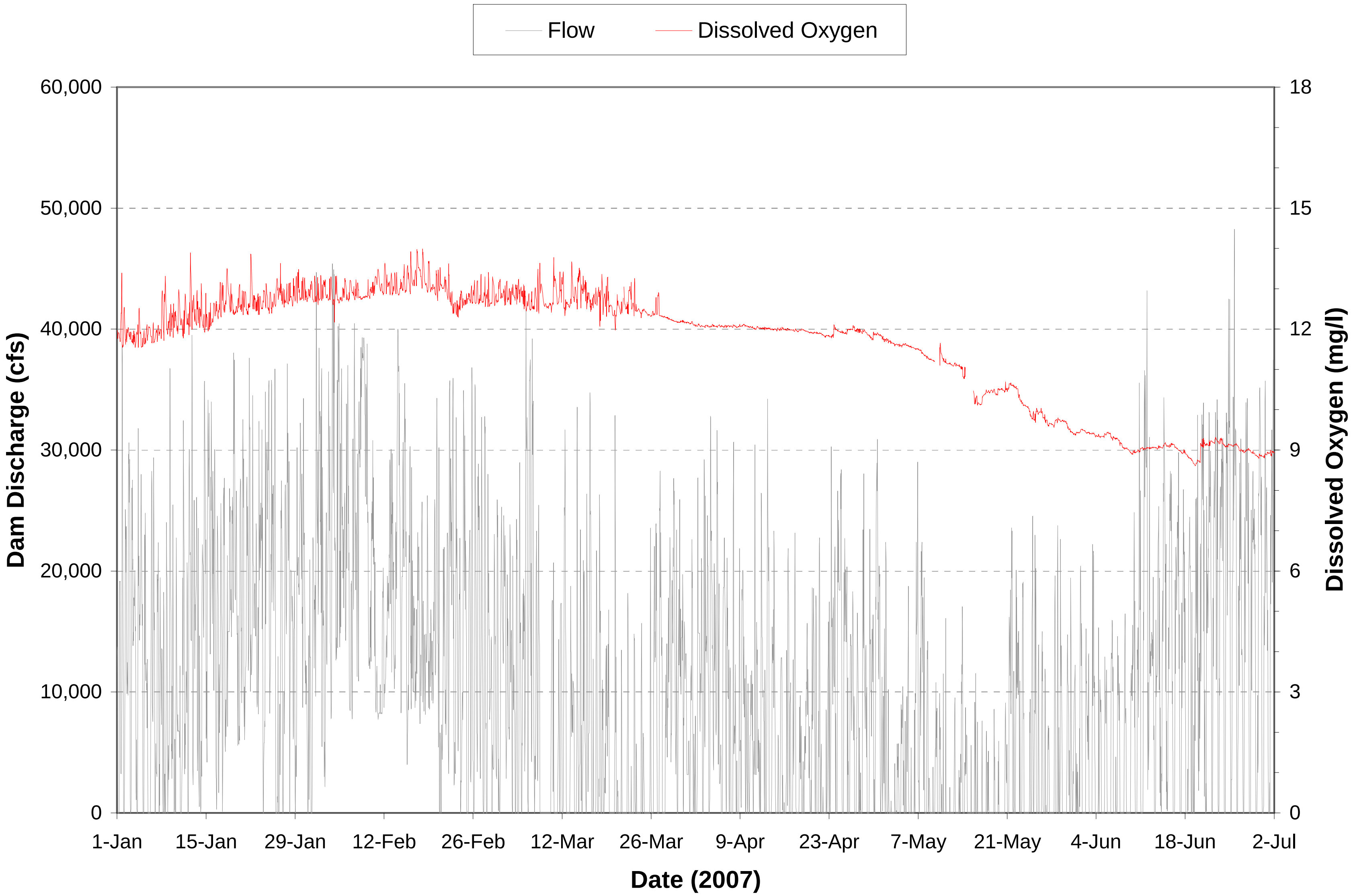


Plate 203. Hourly discharge and dissolved oxygen monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2007.

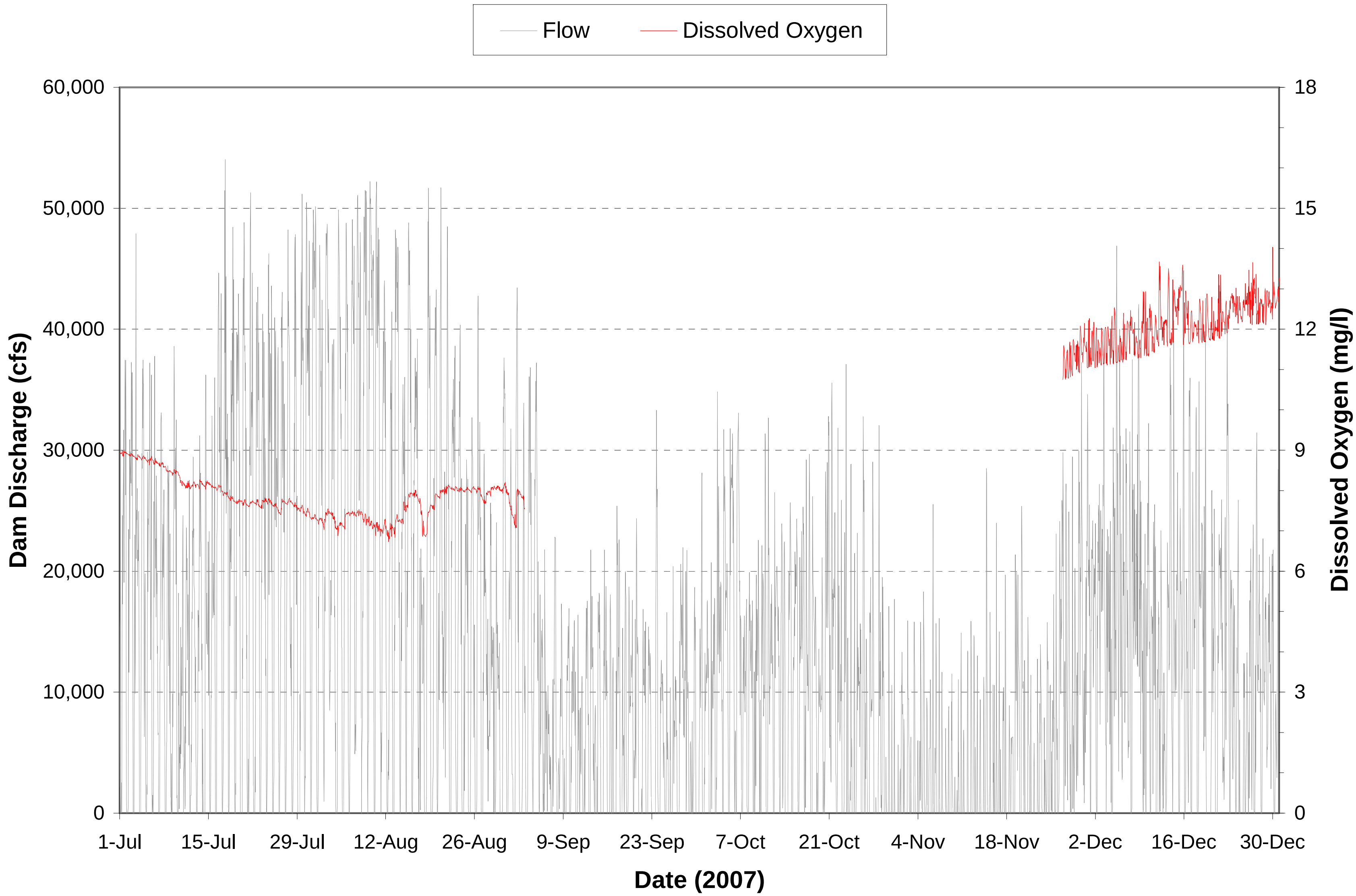


Plate 204. Hourly discharge and dissolved oxygen monitored at the Oahe Powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

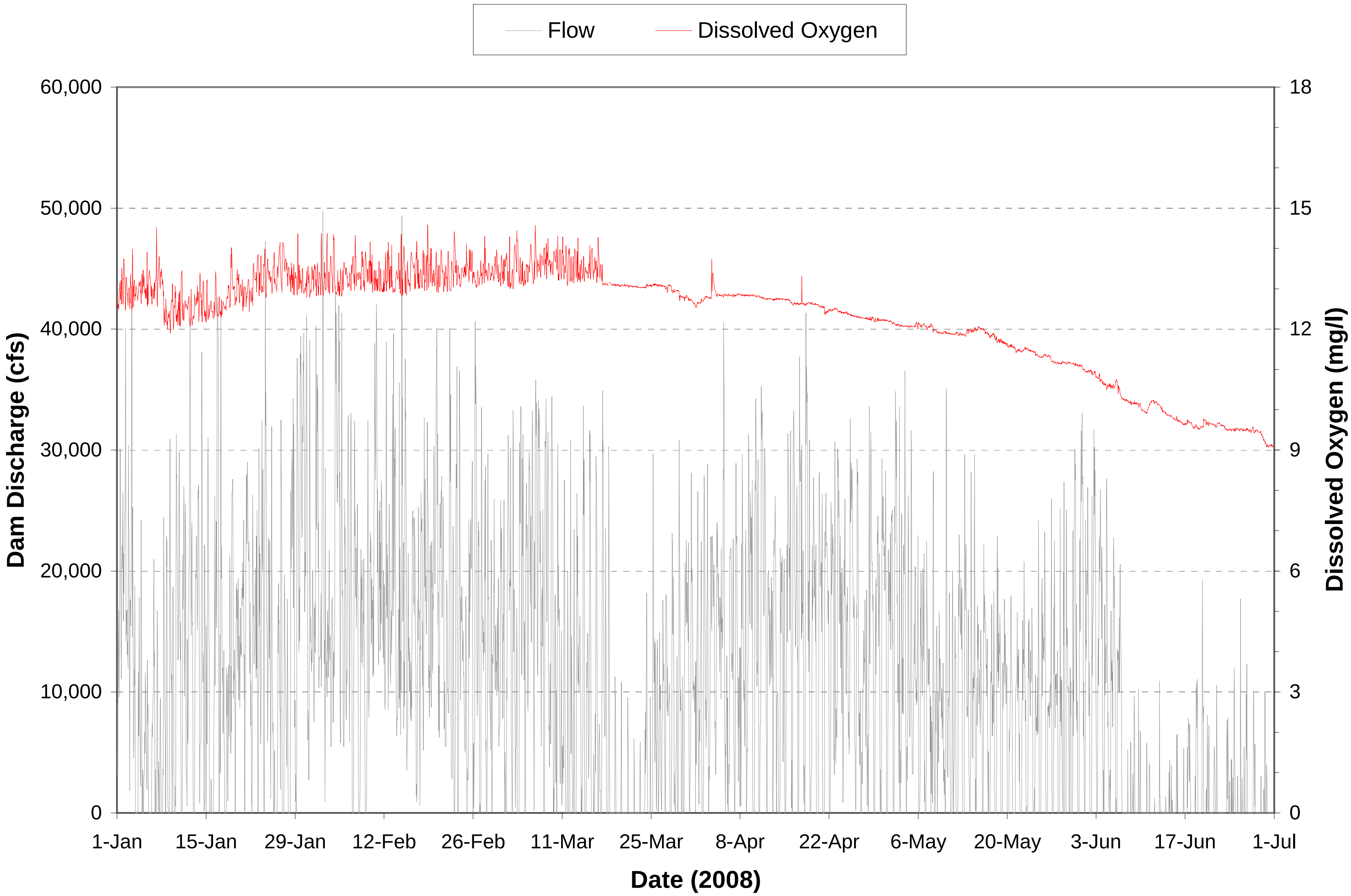


Plate 205. Hourly discharge and dissolved oxygen monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2008.

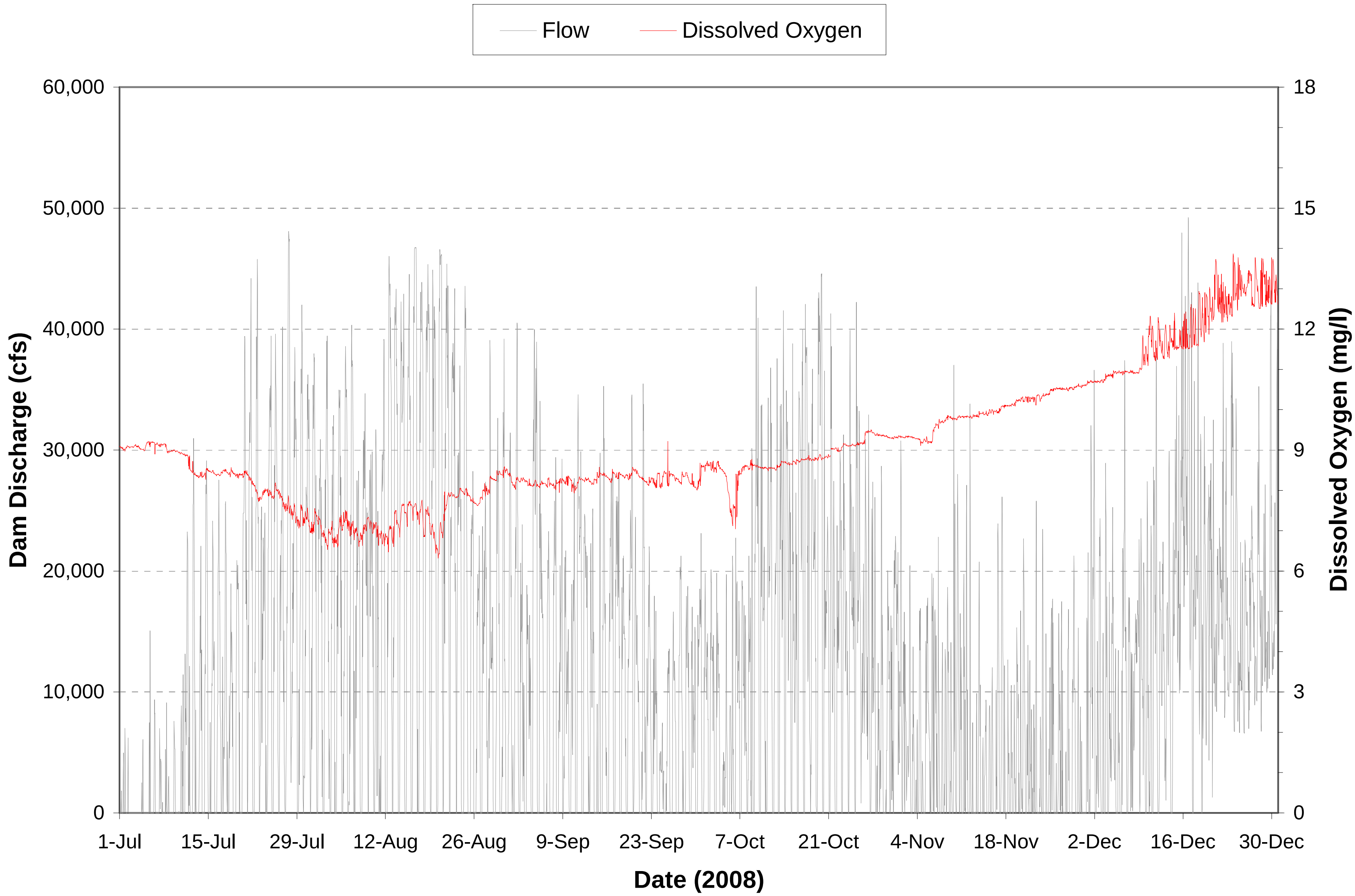


Plate 206. Hourly discharge and dissolved oxygen monitored at the Oahe Powerplant on water discharged through the dam during the period July through December 2008.

Plate 207. Hourly discharge and dissolved oxygen monitored at the Oahe Powerplant on water discharged through the dam during the period January through June 2009.

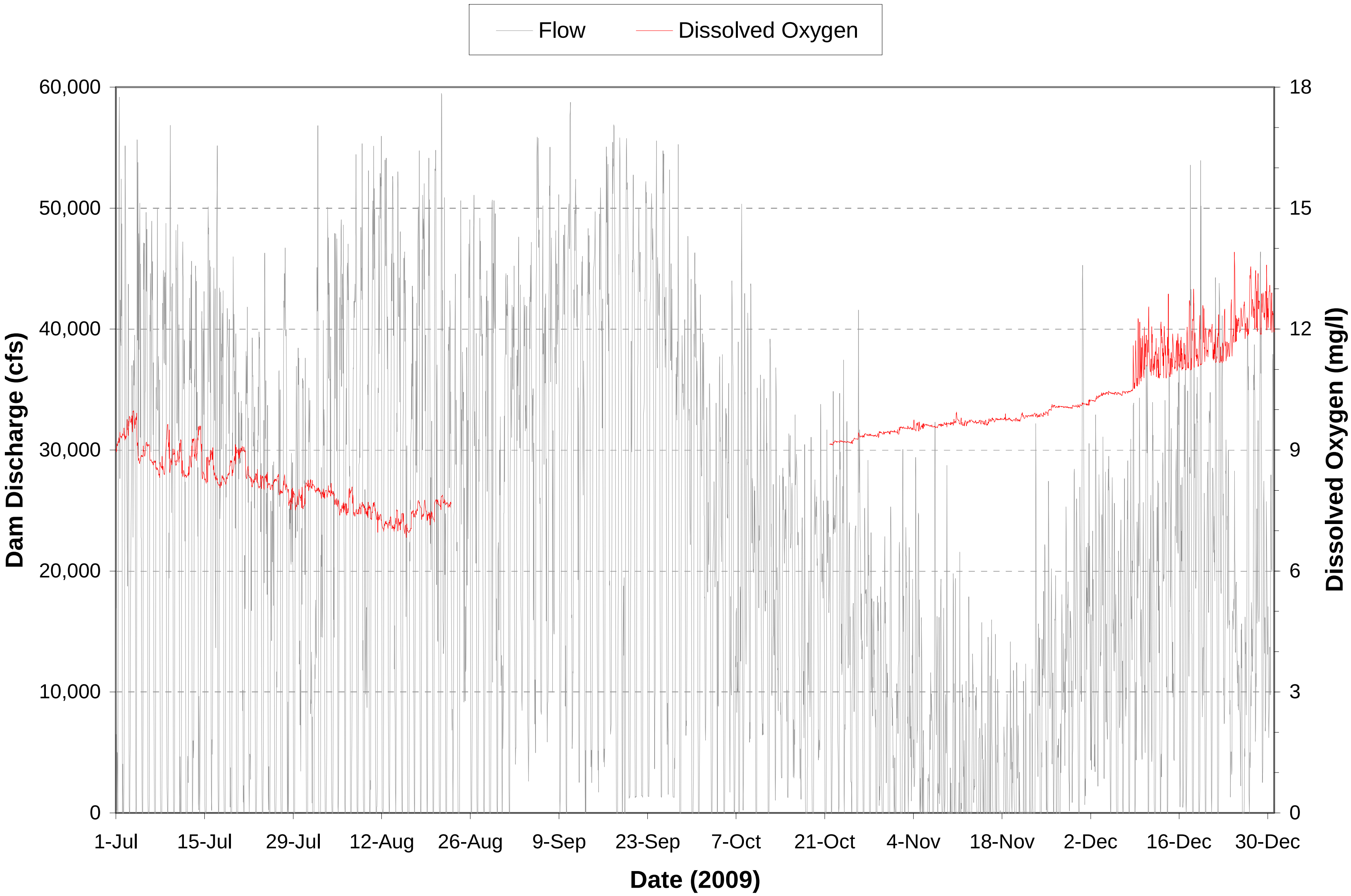


Plate 208. Hourly discharge and dissolved oxygen monitored at the Oahe Powerplant on water discharged through the dam during the period July through December 2009.

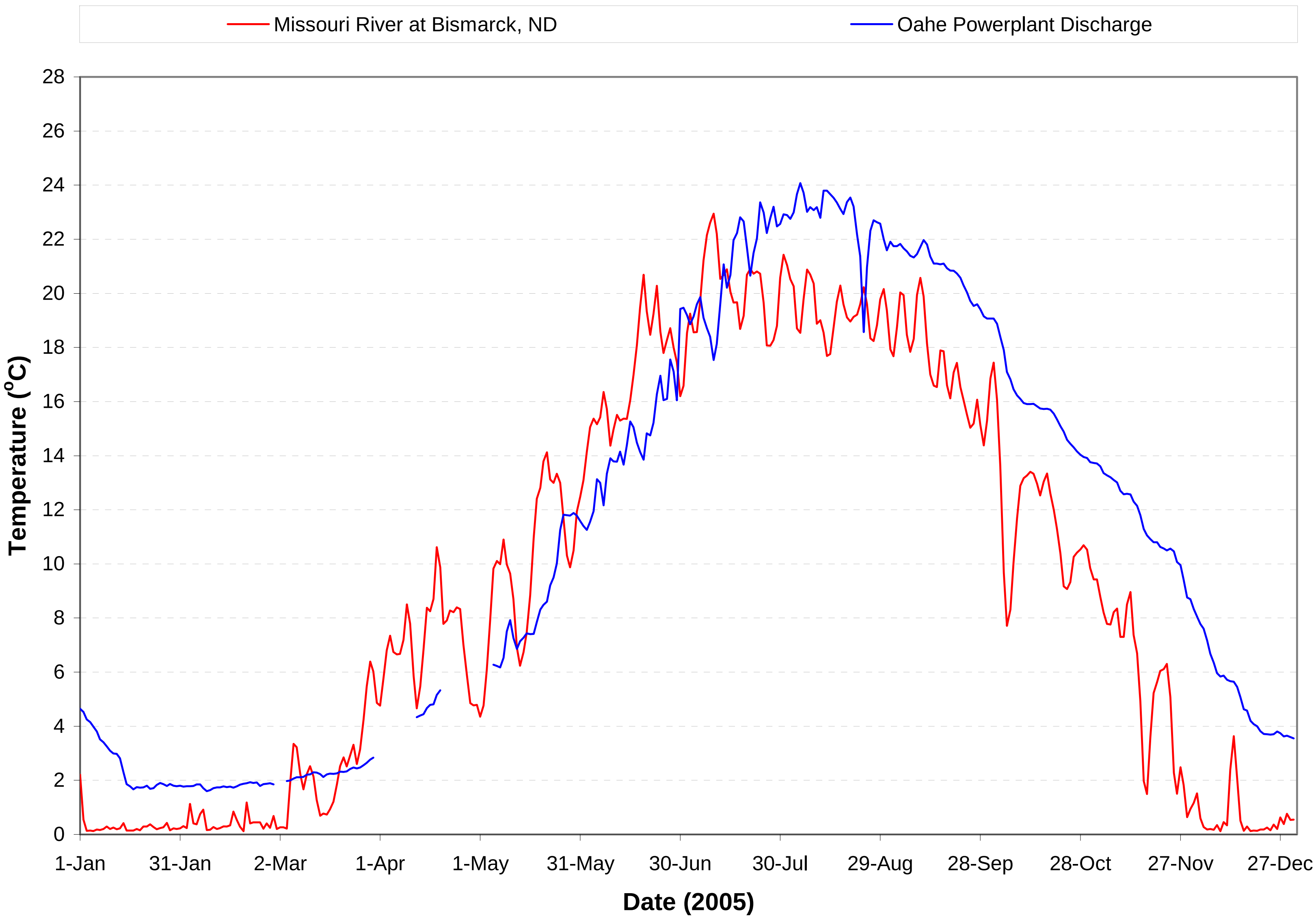


Plate 209. Mean daily water temperatures monitored at the Oahe Powerplant (i.e., site OAHPP1) and the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) during 2005.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

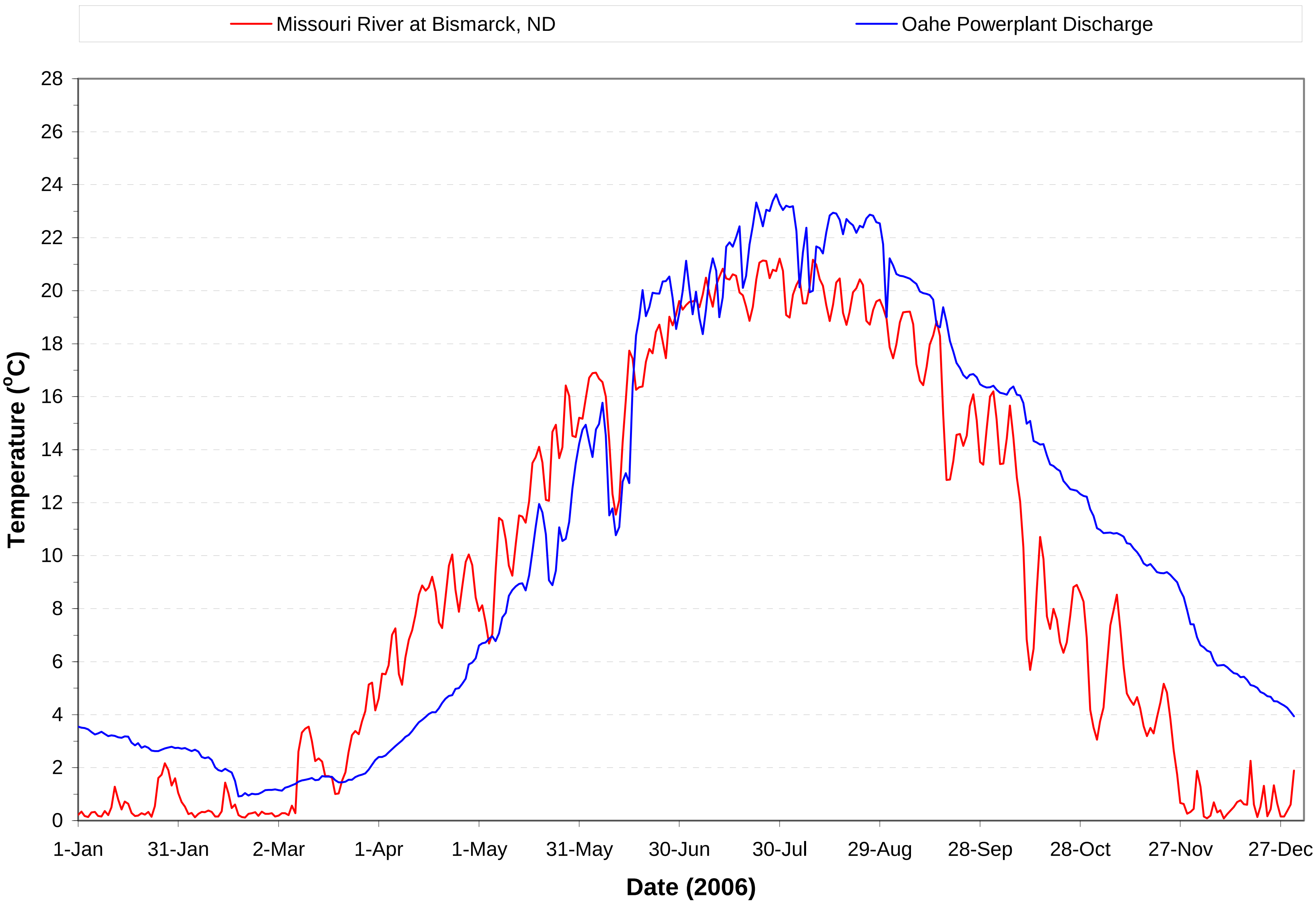


Plate 210. Mean daily water temperatures monitored at the Oahe Powerplant (i.e., site OAHPP1) and the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) during 2006.

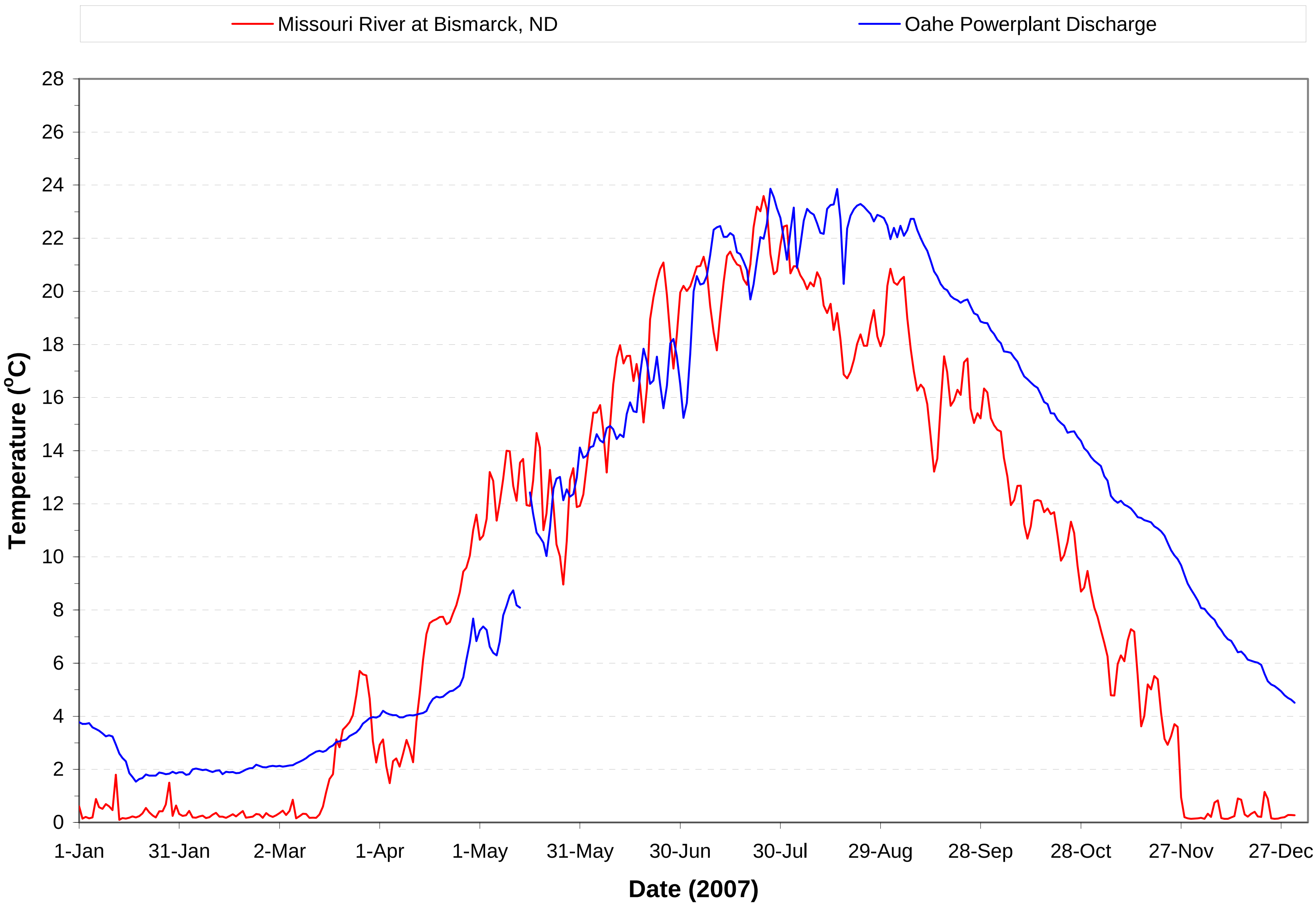


Plate 211. Mean daily water temperatures monitored at the Oahe Powerplant (i.e., site OAHPP1) and the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) during 2007.

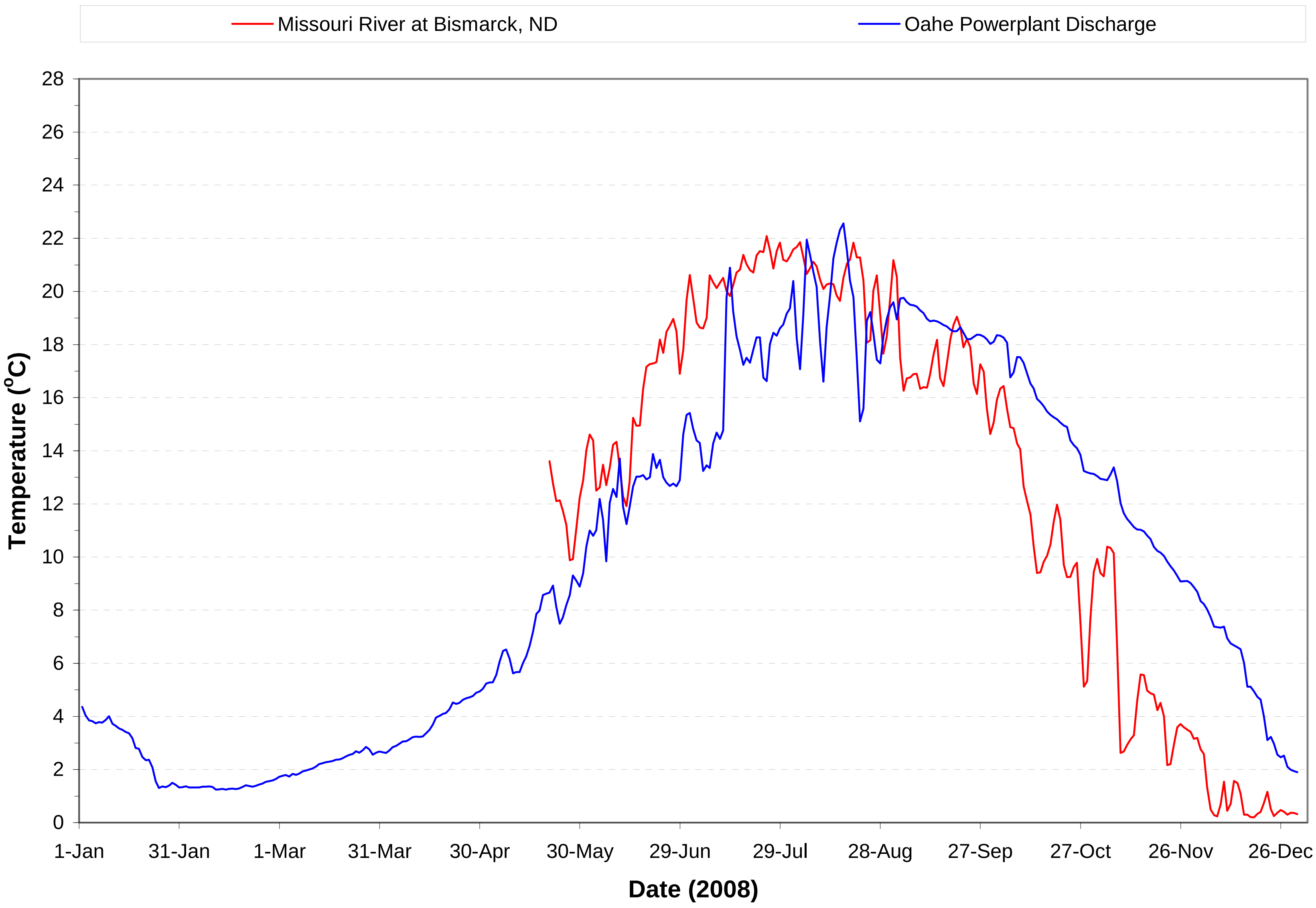


Plate 212. Mean daily water temperatures monitored at the Oahe Powerplant (i.e., site OAHPP1) and the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) during 2008.

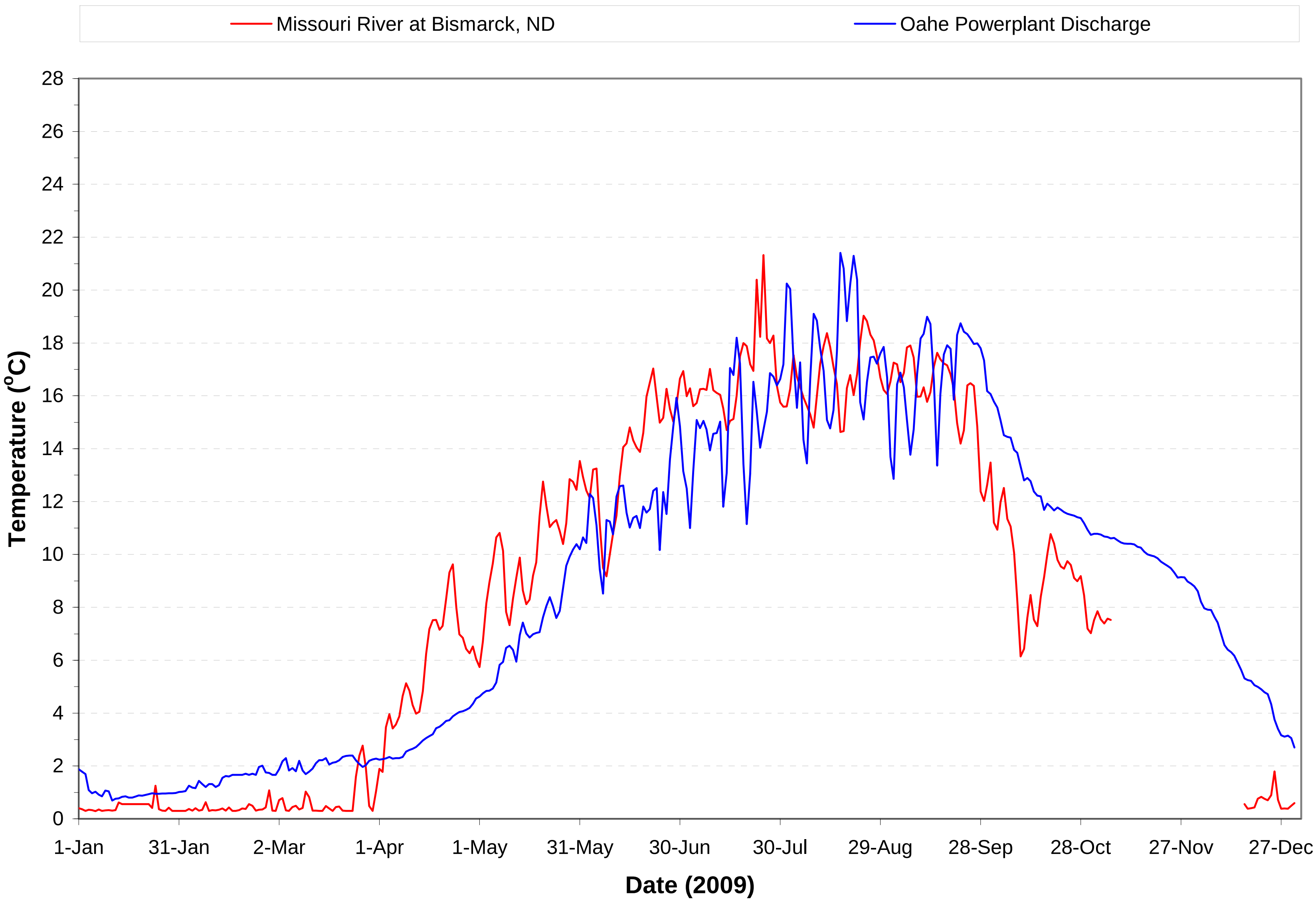


Plate 213. Mean daily water temperatures monitored at the Oahe Powerplant (i.e., site OAHPP1) and the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) during 2009.

Plate 214. Summary of monthly (May through September) water quality conditions monitored in Lake Sharpe near Big Bend Dam (Site BBDLK0987A) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results[(A)]						Water Quality Standards Attainment		
	Detection Limit[(B)]	No. of Obs.	Mean[(C)]	Median	Min.	Max.	State WQS Criteria[(D)]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	25	1420.4	1420.4	1419.9	1420.9	-----	-----	-----
Water Temperature (°C)	0.1	559	19.4	20.6	9.7	27.3	18.3[(1,5)]	352	63%
Hypolimnion Water Temperature (°C)[(E)]	0.1	14	20.4	20.8	18.5	23.4	18.3[(1,5)]	14	100%
Dissolved Oxygen (mg/l)	0.1	559	8.2	8.1	3.1	10.8	6[(1,6,8)], 7[(1,6,8)]	24, 81	4%, 14%
Dissolved Oxygen (% Sat.)	0.1	559	91.8	94.5	37.2	108.7	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[(E)]	0.1	546	8.3	8.1	4.8	10.8	5[(3,6)]	1	<1%
Hypolimnion Dissolved Oxygen (mg/l)[(E)]	0.1	14	4.5	4.8	3.1	6.4	6[(1,6,8)]	13	93%
Specific Conductance (umho/cm)	1	558	706	713	546	796	-----	-----	-----
pH (S.U.)	0.1	536	8.4	8.4	7.6	9.0	6.5[(1,2,6)], 9.0[(1,2,5)], 9.5[(4,5)]	0	0%
Turbidity (NTUs)	1	557	-----	3	n.d.	38	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	491	338	332	255	441	-----	-----	-----
Secchi Depth (in.)	1	25	89	74	30	228	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	161	159	140	180	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	46	3.0	3.1	1.5	4.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	42	10	10	n.d.	20	-----	-----	-----
Chloride (mg/l)	1	42	11	11	9	14	175[(1,5)], 100[(1,7)], 438[(2,5)], 250[(2,7)]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	279	12	5	1	73	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	24	5	3	n.d.	26	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	44	494	483	440	616	1,750[(2,5)], 1,000[(2,7)], 3,500[(4,5)], 2,000[(4,7)]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	48	-----	0.02	n.d.	0.19	2.6 [(1,5,9)], 0.83 [(1,7,9)]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	48	-----	0.3	n.d.	1.0	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	48	-----	n.d.	n.d.	0.11	10[(2,5)]	0	0%
Nitrogen, Total (mg/l)	0.1	48	-----	0.3	n.d.	1.1	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	38	-----	n.d.	n.d.	0.18	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	48	0.04	0.03	n.d.	0.24	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	48	-----	n.d.	n.d.	0.16	-----	-----	-----
Sulfate (mg/l)	1	44	205	210	165	238	875[(2,5)], 500[(2,7)]	0	0%
Suspended Solids, Total (mg/l)	4	48	-----	n.d.	n.d.	11	53[(1,5)], 30[(1,7)]	0	0%
Microcystin, Total (ug/l)	0.2	23	-----	n.d.	n.d.	0.3	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[(F)]	-----	25	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	15	60%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of 1.0°C or at least 0.5°C occurs over a 1-meter depth increment. A defined hypolimnion was monitored on 4 of the 25 occasions (i.e., 16%) that monthly depth profiles were measured from May through September. Measured water depths in this area of Lake Sharpe were < 23 meters.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile. During the 5-year period 2005 through 2009, water temperatures greater than 18.3°C throughout the water column precluded the occurrence of Coldwater Permanent Fish Life Propagation habitat from late-June through early-September.

Plate 215. Summary of monthly (June through September) water quality conditions monitored at Lake Sharpe in the North Bend area (site BBDLK1004DW) during the 2-year period 2008 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	7	1420.3	1420.4	1419.7	1420.8	-----	-----	-----
Water Temperature (°C)	0.1	126	21.0	21.1	14.5	26.8	18.3[1,5]	108	86%
Hypolimnion Water Temperature (°C)[E]	0.1	14	21.1	21.3	19.0	22.8	18.3[1,5]	14	100%
Dissolved Oxygen (mg/l)	0.1	126	8.2	8.4	5.2	9.7	6[1,6,8], 7[1,6,8]	2, 22	2%, 17%
Dissolved Oxygen (% Sat.)	0.1	126	94.9	97.7	65.3	113.5	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	112	8.2	8.4	5.2	9.7	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	14	7.8	7.8	6.1	9.7	6[1,6,8]	0	0%
Specific Conductance (umho/cm)	1	126	728	727	704	756	-----	-----	-----
pH (S.U.)	0.1	126	8.4	8.3	7.8	8.9	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	126	4	4	n.d.	16	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	108	333	319	254	462	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	123	10	7	2	27	-----	-----	-----
Secchi Depth (in)	1	7	74	67	48	146	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[f]	-----	7	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	6	86%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment. A defined hypolimnion was monitored on 1 of the 7 occasions (i.e., 14%) that monthly depth profiles were measured from June through September. Measured water depths in this area of Lake Sharpe were < 18 meters.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile. During the 2-year period 2008 through 2009, water temperatures greater than 18.3°C throughout the water column precluded the occurrence of Coldwater Permanent Fish Life Propagation habitat from late-June through mid-September.

Plate 216. Summary of monthly (May through September) water quality conditions monitored in Lake Sharpe in the Iron Nation area (Site BBDLK1020DW) during the 2-year period 2008 through 2009.

Parameter	Monitoring Results[(A)]						Water Quality Standards Attainment		
	Detection Limit[(B)]	No. of Obs.	Mean[(C)]	Median	Min.	Max.	State WQS Criteria[(D)]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	8	1420.3	1420.4	1419.8	1420.9	-----	-----	-----
Water Temperature (°C)	0.1	100	20.0	19.9	15.1	27.3	18.3[(1,5)]	66	66%
Hypolimnion Water Temperature (°C)[(E)]	0.1	8	21.8	21.8	21.6	22.1	18.3[(1,5)]	8	100%
Dissolved Oxygen (mg/l)	0.1	99	8.6	8.8	6.4	10.3	6[(1,6,8)], 7[(1,6,8)]	0, 6	0%, 6%
Dissolved Oxygen (% Sat.)	0.1	99	97.6	97.8	75.9	133.9	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[(E)]	0.1	91	8.7	8.8	7.1	10.3	5[(3,6)]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[(E)]	0.1	8	6.7	6.5	6.4	7.2	6[(1,6,8)]	0	0%
Specific Conductance (umho/cm)	1	99	726	726	700	770	-----	-----	-----
pH (S.U.)	0.1	99	8.3	8.3	8.0	8.6	6.5[(1,2,6)], 9.0[(1,2,5)], 9.5[(4,5)]	0	0%
Turbidity (NTUs)	1	100	8	7	2	22	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	87	334	339	256	408	-----	-----	-----
Secchi Depth (in.)	1	8	43	37	24	96	-----	-----	-----
Alkalinity, Total (mg/l)	7	16	156	158	144	165	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	16	3.3	2.9	2.4	5.0	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	16	12	12	7	18	-----	-----	-----
Chloride (mg/l)	1	16	12	12	11	13	175[(1,5)], 100[(1,7)], 438[(2,5)], 250[(2,7)]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	97	9	7	3	17	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	8	9	8	5	13	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	16	540	514	464	726	1,750[(2,5)], 1,000[(2,7)], 3,500[(4,5)], 2,000[(4,7)]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	16	-----	n.d.	n.d.	0.20	3.1 [(1,5,9)], 1.0 [(1,7,9)]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	16	0.7	0.6	0.2	1.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	16	-----	n.d.	n.d.	0.05	10[(2,5)]	0	0%
Nitrogen, Total (mg/l)	0.1	16	0.7	0.6	0.2	1.4	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	16	-----	n.d.	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	16	0.04	0.03	n.d.	0.21	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	16	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	16	205	208	182	222	875[(2,5)], 500[(2,7)]	0	0%
Suspended Solids, Total (mg/l)	4	16	-----	5	n.d.	20	53[(1,5)], 30[(1,7)]	0	0%
Microcystin, Total (ug/l)	0.2	8	-----	n.d.	n.d.	0.2	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[(F)]	-----	8	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	5	63%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of 1.0°C or at least 0.5°C occurs over a 1-meter depth increment. A defined hypolimnion was monitored on 1 of the 8 occasions (i.e., 13%) that monthly depth profiles were measured from June through September. Measured water depths in this area of Lake Sharpe were < 12.5 meters.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile. During the 2-year period 2008 through 2009, water temperatures greater than 18.3°C throughout the water column precluded the occurrence of Coldwater Permanent Fish Life Propagation habitat from late-June through early-September.

Plate 217. Summary of monthly (June through September) water quality conditions monitored at Lake Sharpe in the Cedar Creek area (site BBDLK1036DW) during the 2-year period 2008 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	7	1420.4	1420.4	1420.0	1420.9	-----	-----	-----
Water Temperature (°C)	0.1	43	19.6	18.1	16.7	24.3	18.3[1,5]	12	50%
Hypolimnion Water Temperature (°C)[E]	0.1	0	-----	-----	-----	-----	18.3[1,5]	-----	-----
Dissolved Oxygen (mg/l)	0.1	43	8.6	8.7	7.6	9.2	6[1,6,8], 7[1,6,8]	0	0%
Dissolved Oxygen (% Sat.)	0.1	43	96.8	96.0	91.6	104.9	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	43	8.6	8.7	7.6	9.2	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0	-----	-----	-----	-----	6[1,6,8]	-----	-----
Specific Conductance (umho/cm)	1	43	760	723	712	908	-----	-----	-----
pH (S.U.)	0.1	43	8.4	8.3	8.0	9.0	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	43	30	27	12	65	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	43	351	319	268	469	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	43	10	10	4	16	-----	-----	-----
Secchi Depth (in)	1	7	13	13	8	20	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	7	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	3	43%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of 1.0°C or at least 0.5°C occurs over a 1-meter depth increment. A defined hypolimnion was not monitored on any of the 7 occasions that monthly depth profiles were measured from June through September. This is attributed to the shallower water depths (<6.5 meters) in this area of Lake Sharpe.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile. During the 2-year period 2008 through 2009, water temperatures greater than 18.3°C throughout the water column precluded the occurrence of Coldwater Permanent Fish Life Propagation habitat in July and August 2008, and August 2009.

Plate 218. Summary of monthly (May through September) water quality conditions monitored in Lake Sharpe in the Antelope Creek area (Site BBDLK1055DW) during the 2-year period 2008 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	8	1420.4	1420.4	1420.0	1420.8	-----	-----	-----
Water Temperature (°C)	0.1	32	18.4	18.7	12.9	22.2	18.3(1,5)	18	56%
Hypolimnion Water Temperature (°C)[E]	0.1	0	-----	-----	-----	-----	18.3(1,5)	-----	-----
Dissolved Oxygen (mg/l)	0.1	32	8.6	8.5	7.7	10.2	6(1,6,8), 7(1,6,8)	0	0%
Dissolved Oxygen (% Sat.)	0.1	32	95.4	94.8	79.7	104.9	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	32	8.6	8.5	7.7	10.2	5(3,6)	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0	-----	-----	-----	-----	6(1,6,8)	-----	-----
Specific Conductance (umho/cm)	1	32	740	718	712	843	-----	-----	-----
pH (S.U.)	0.1	32	8.3	8.3	8.0	8.9	6.5(1,2,6), 9.0(1,2,5), 9.5(4,5)	0	0%
Turbidity (NTUs)	1	32	58	42	9	188	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	32	340	319	267	474	-----	-----	-----
Secchi Depth (in.)	1	8	13	9	6	26	-----	-----	-----
Alkalinity, Total (mg/l)	7	8	152	157	122	159	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	8	3.8	3.0	2.6	9.1	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	8	11	11	5	20	-----	-----	-----
Chloride (mg/l)	1	8	12	12	10	16	175(1,5), 100(1,7), 438(2,5), 250(2,7)	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	30	7	6	2	12	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	8	7	7	2	11	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	8	597	561	464	958	1,750(2,5), 1,000(2,7), 3,500(4,5), 2,000(4,7)	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	8	-----	0.04	n.d.	0.27	3.1 (1,5,9), 1.1 (1,7,9)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	8	1.6	0.5	n.d.	9.1	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	8	-----	0.02	n.d.	1.20	10(2,5)	0	0%
Nitrogen, Total (mg/l)	0.1	8	1.8	0.5	n.d.	10.3	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	8	-----	n.d.	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	8	0.08	0.07	0.02	0.26	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	8	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	8	213	206	190	274	875(2,5), 500(2,7)	0	0%
Suspended Solids, Total (mg/l)	4	8	70	40	7	285	53(1,5), 30(1,7)	3, 5	38%, 63%
Microcystin, Total (ug/l)	0.2	8	-----	n.d.	n.d.	0.2	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	8	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	4	50%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of 1.0°C or at least 0.5°C occurs over a 1-meter depth increment. A defined hypolimnion was not monitored on any of the 8 occasions that monthly depth profiles were measured from June through September. This is attributed to the shallower water depths (<5 meters) in this area of Lake Sharpe.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile. During the 5-year period 2005 through 2009, water temperatures greater than 18.3°C throughout the water column precluded the occurrence of Coldwater Permanent Fish Life Propagation habitat from late-June through early-September.

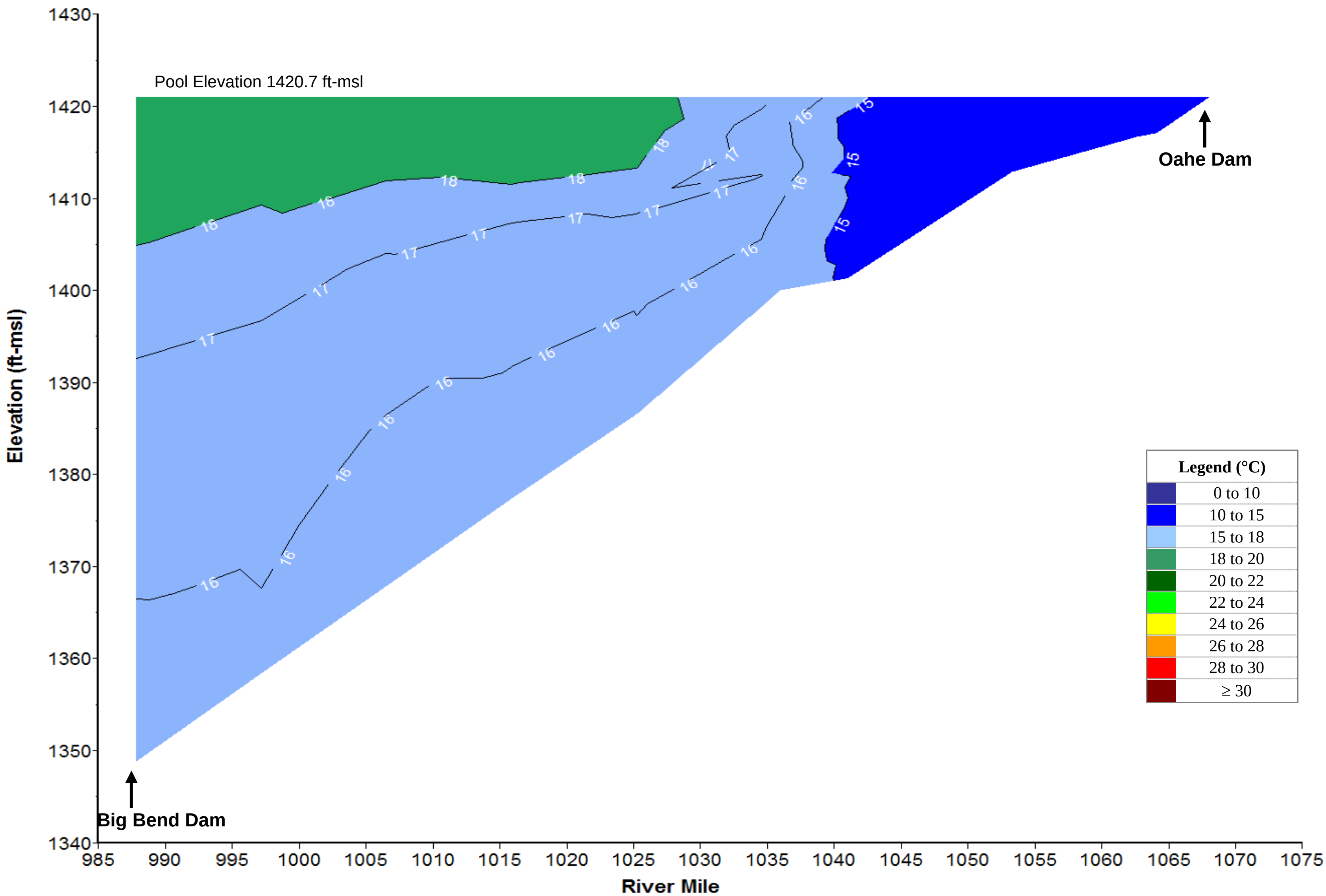


Plate 219. Longitudinal water temperature (°C) contour plot of Lake Sharpe based on depth-profile water temperatures measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on June 17, 2009.

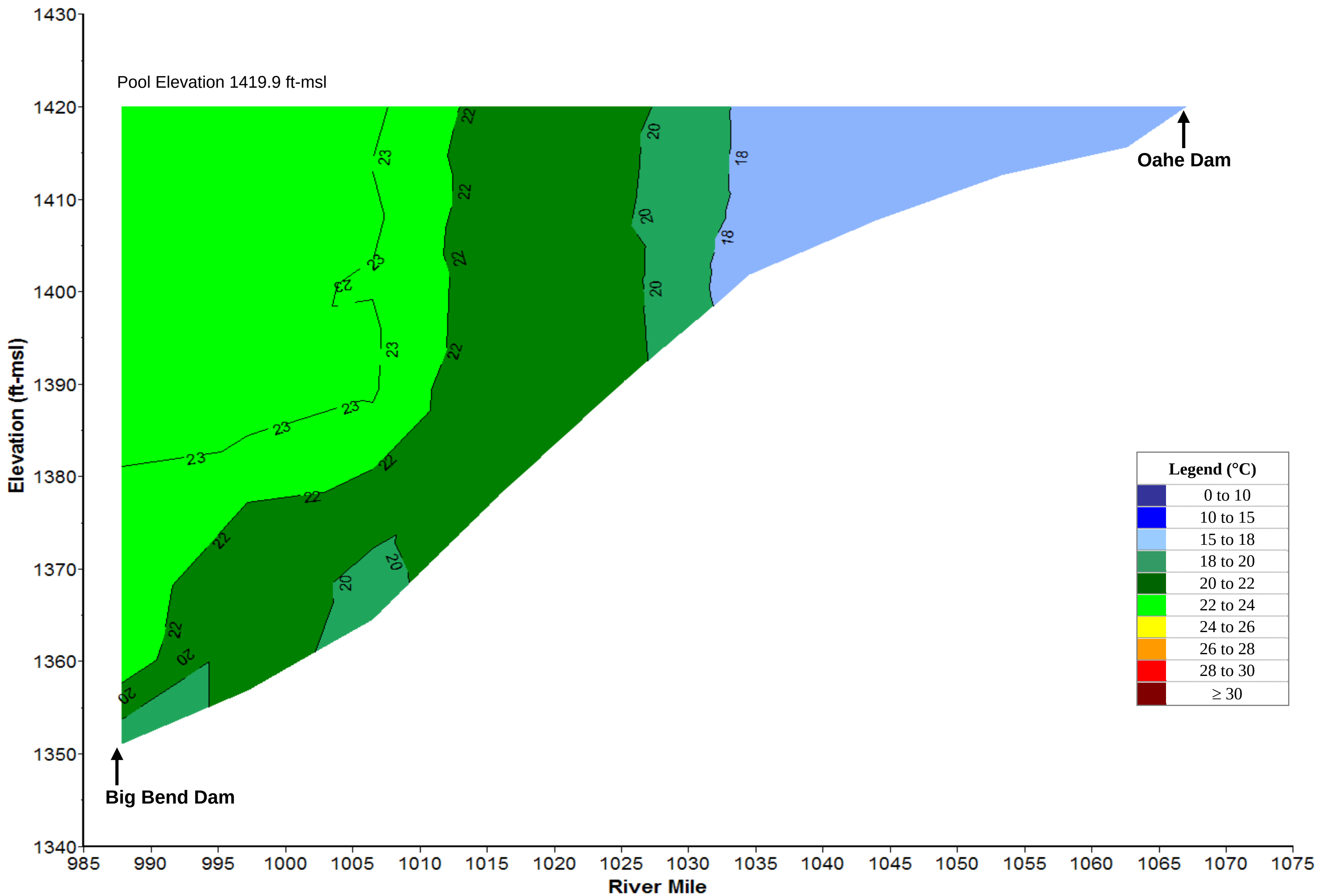


Plate 220. Longitudinal water temperature (°C) contour plot of Lake Sharpe based on depth-profile water temperatures measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on July 15, 2009.

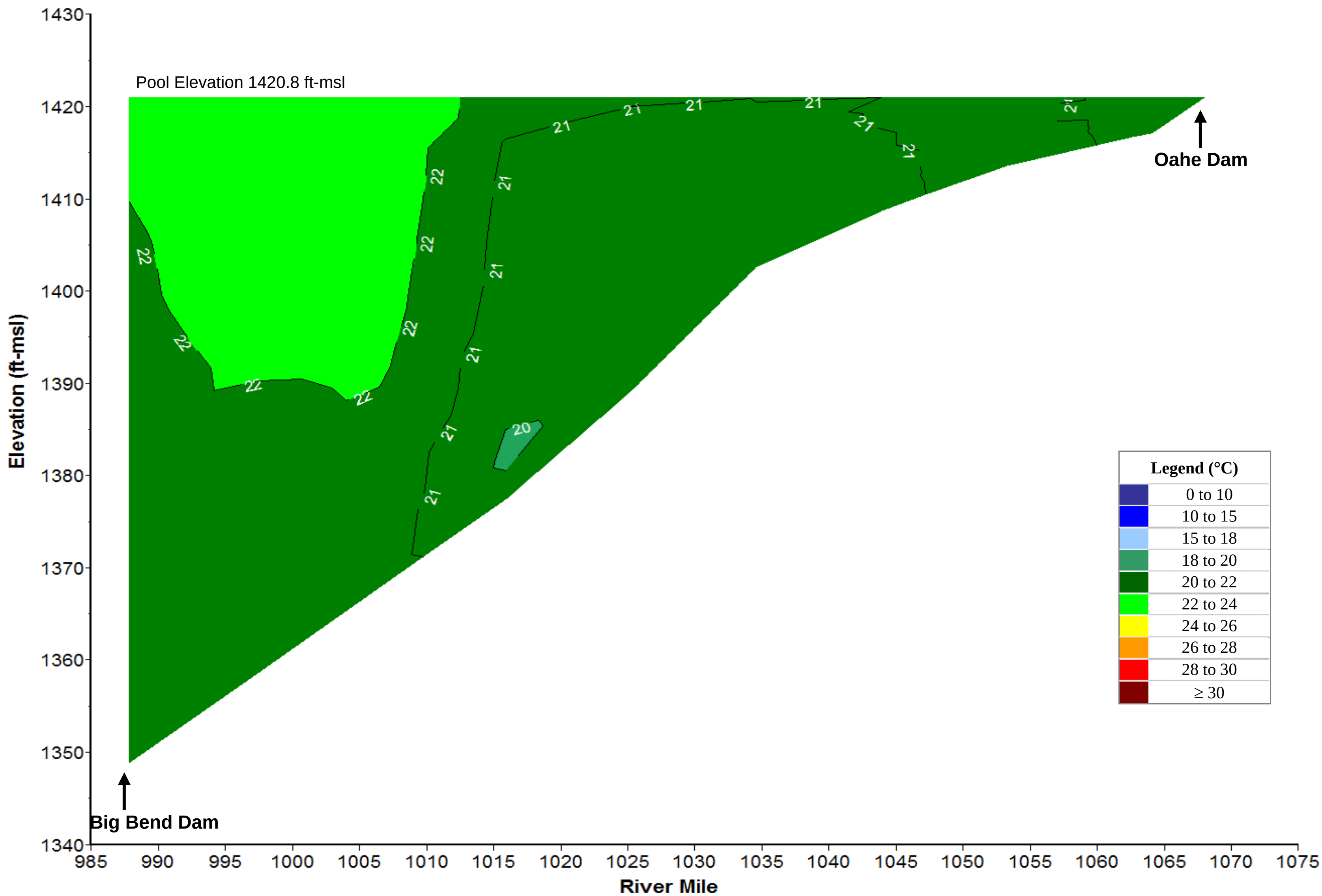


Plate 221. Longitudinal water temperature (°C) contour plot of Lake Sharpe based on depth-profile water temperatures measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on August 18, 2009.

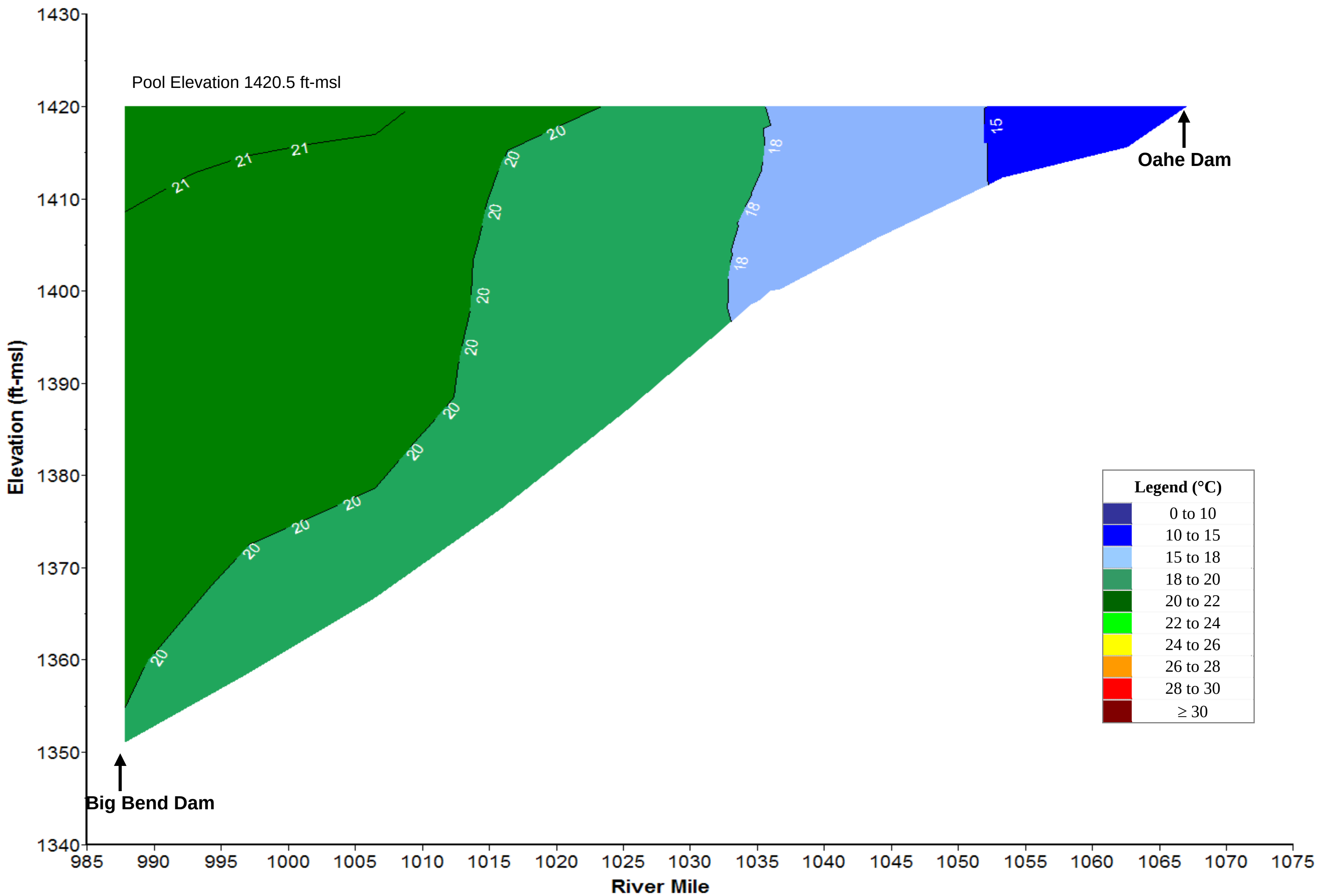


Plate 222. Longitudinal water temperature (°C) contour plot of Lake Sharpe based on depth-profile water temperatures measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on September 16, 2009.

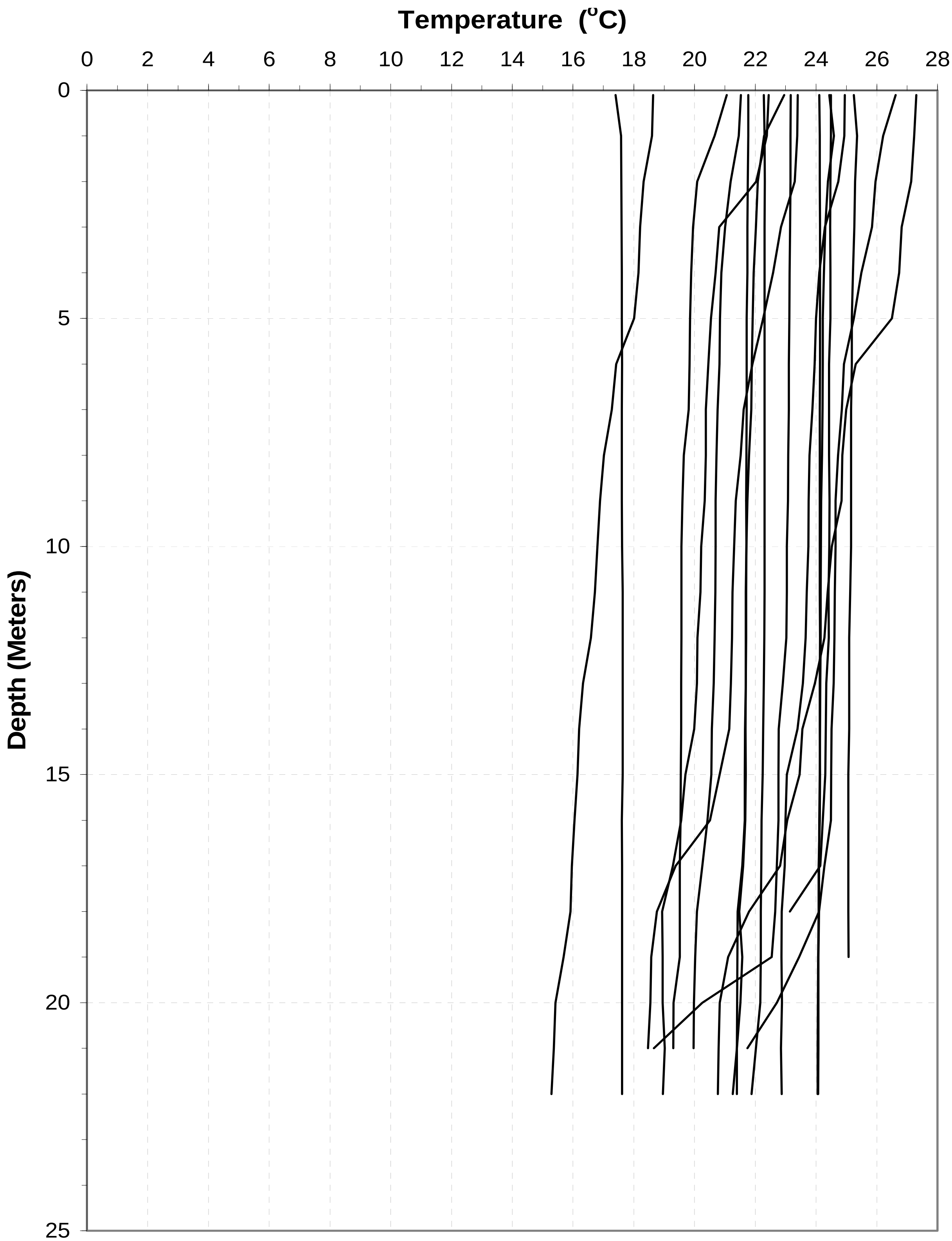


Plate 223. Temperature depth profiles for Lake Sharpe generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., BBDLK0987A) during the summer months of the 5-year period 2005 to 2009.

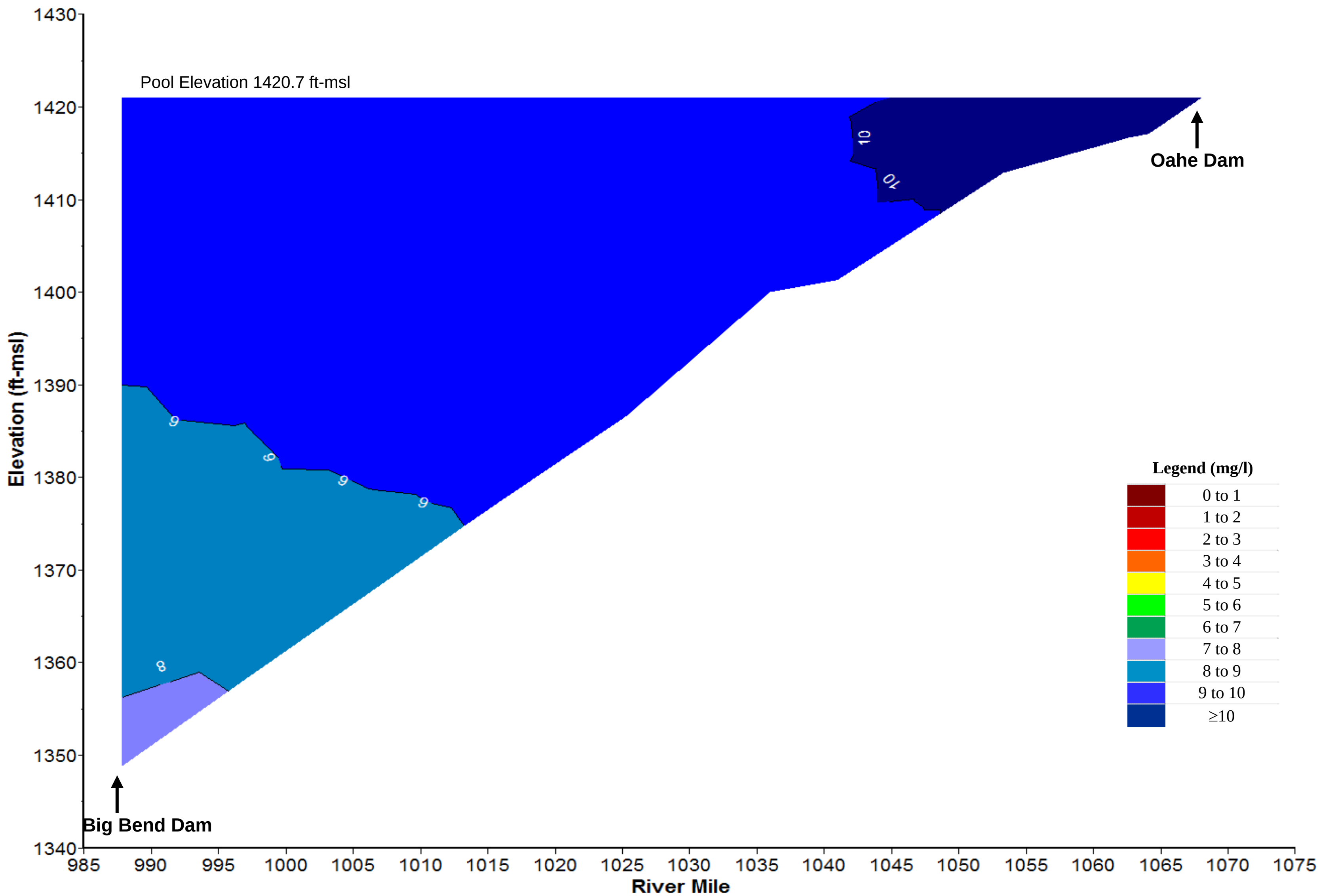


Plate 224. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sharpe based on depth-profile dissolved oxygen concentrations measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on June 17, 2009.

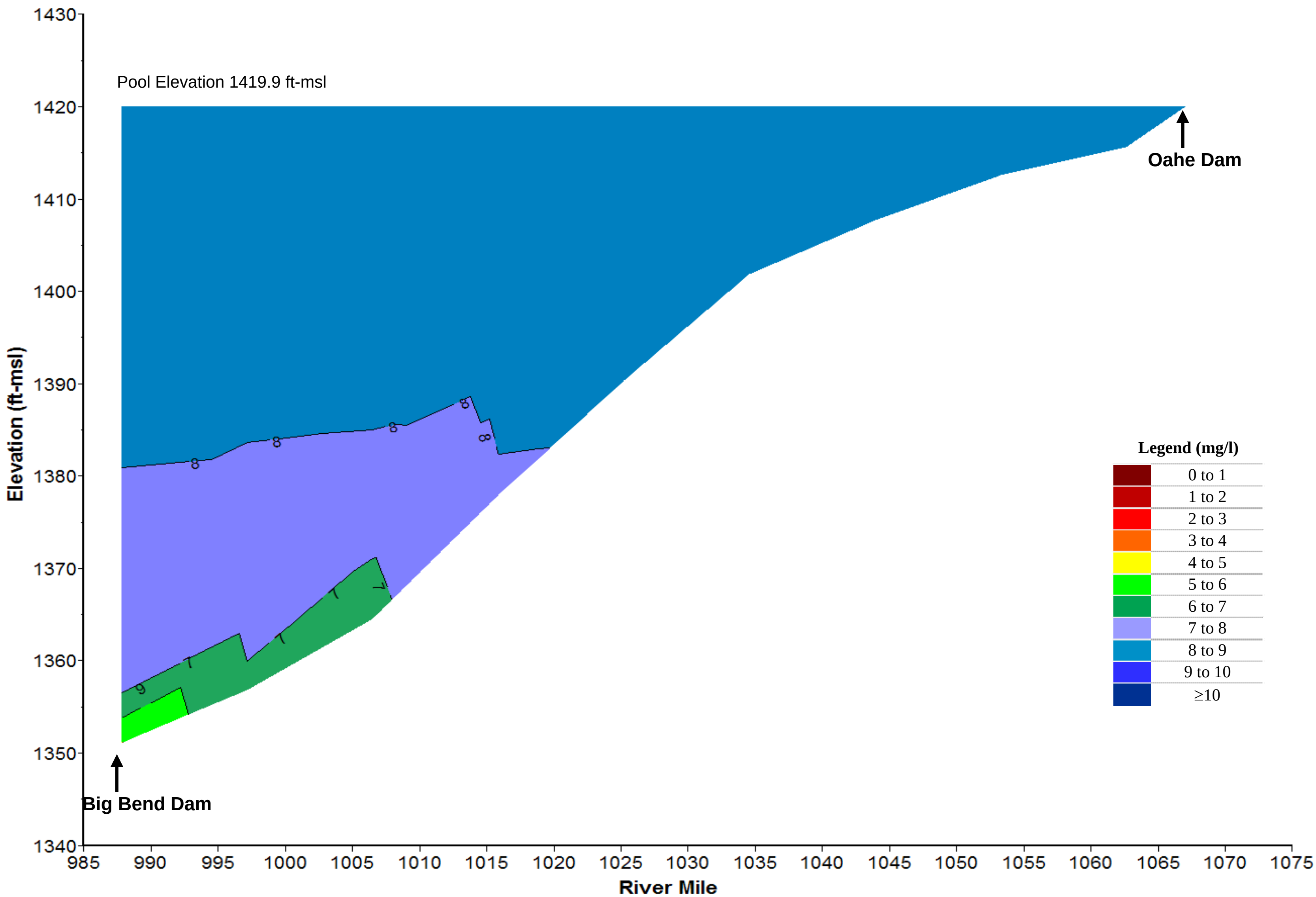


Plate 225. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sharpe based on depth-profile dissolved oxygen concentrations measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on July 15, 2009.

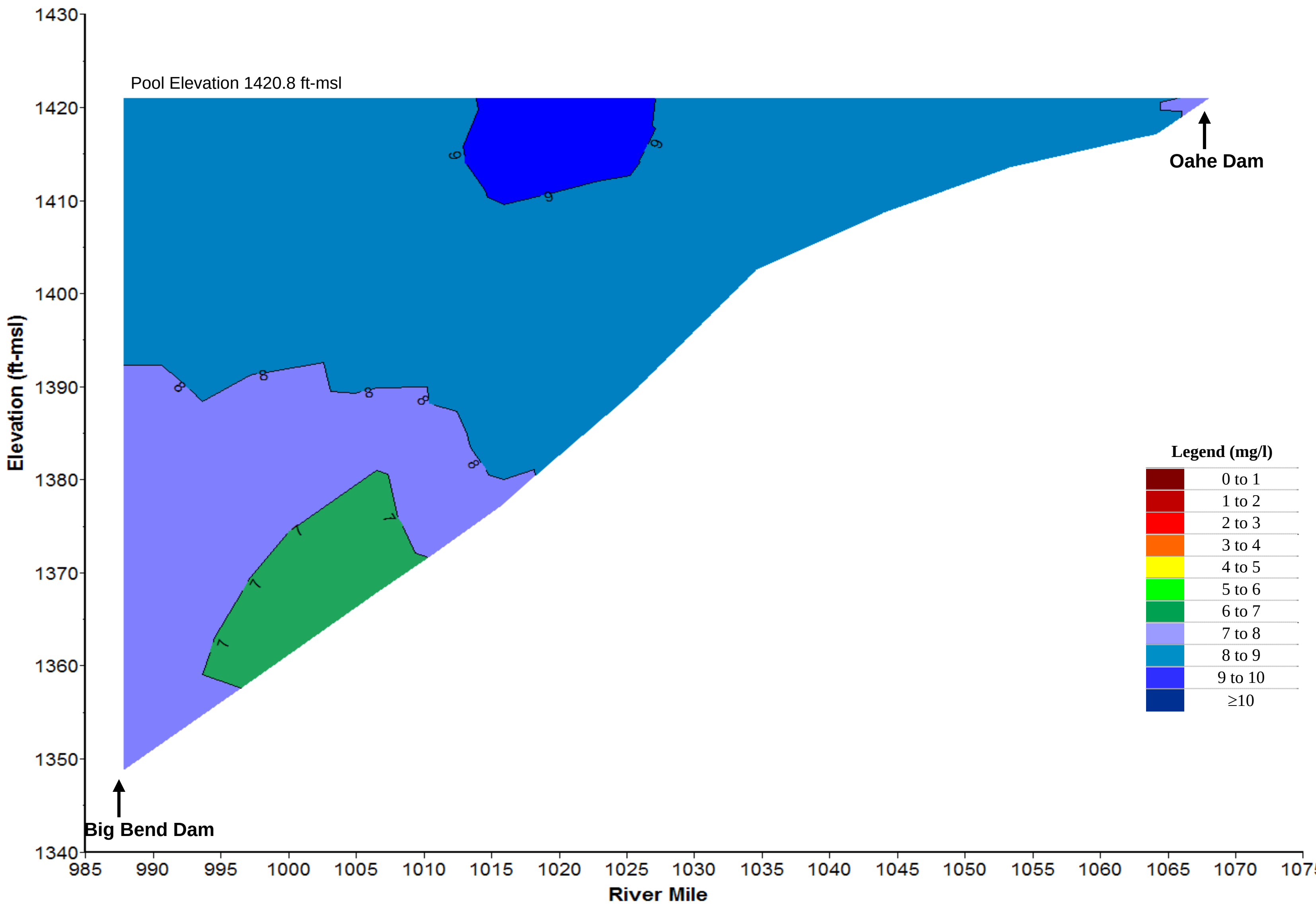


Plate 226. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sharpe based on depth-profile dissolved oxygen concentrations measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on August 18, 2009.

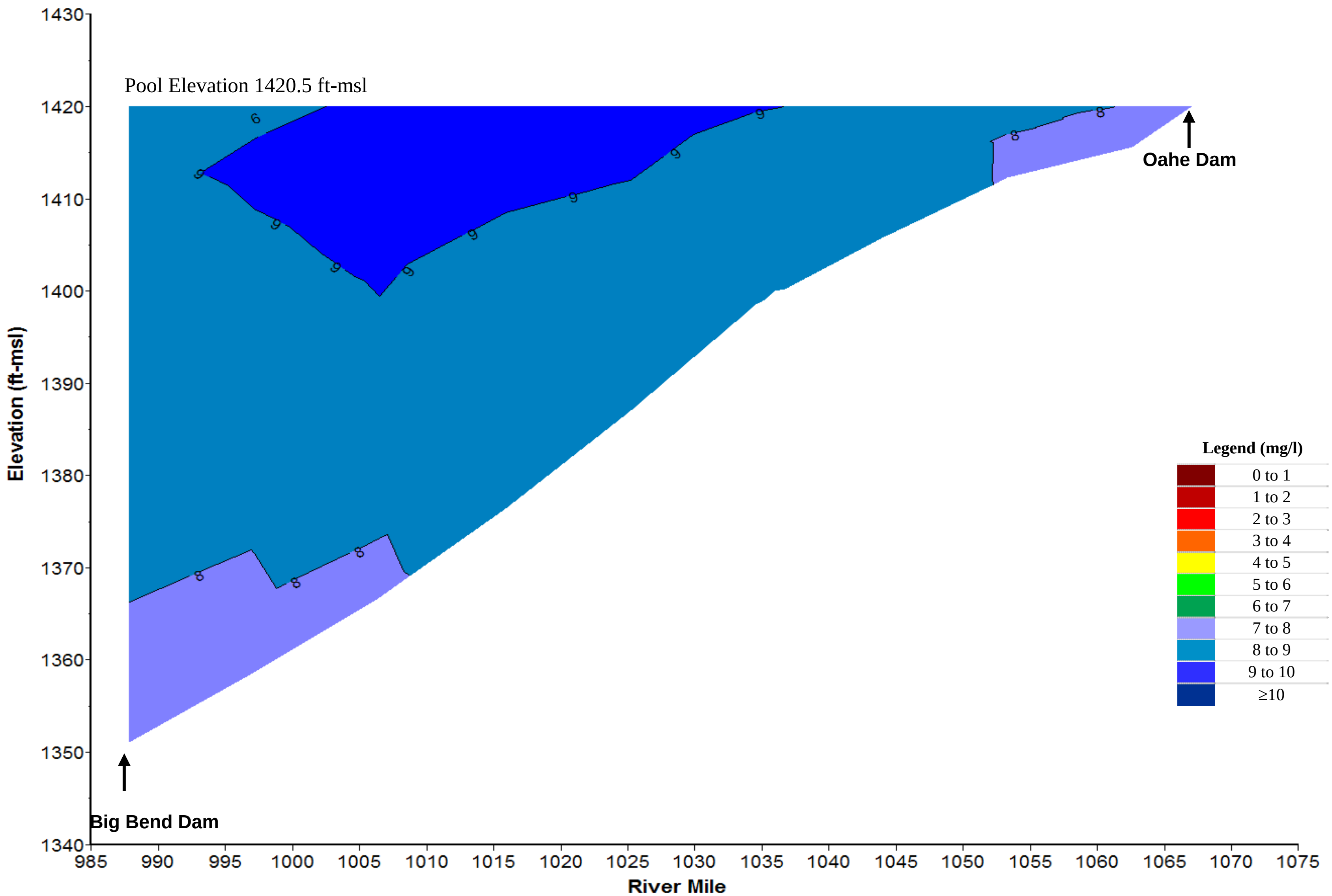


Plate 227. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sharpe based on depth-profile dissolved oxygen concentrations measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on September 16, 2009.

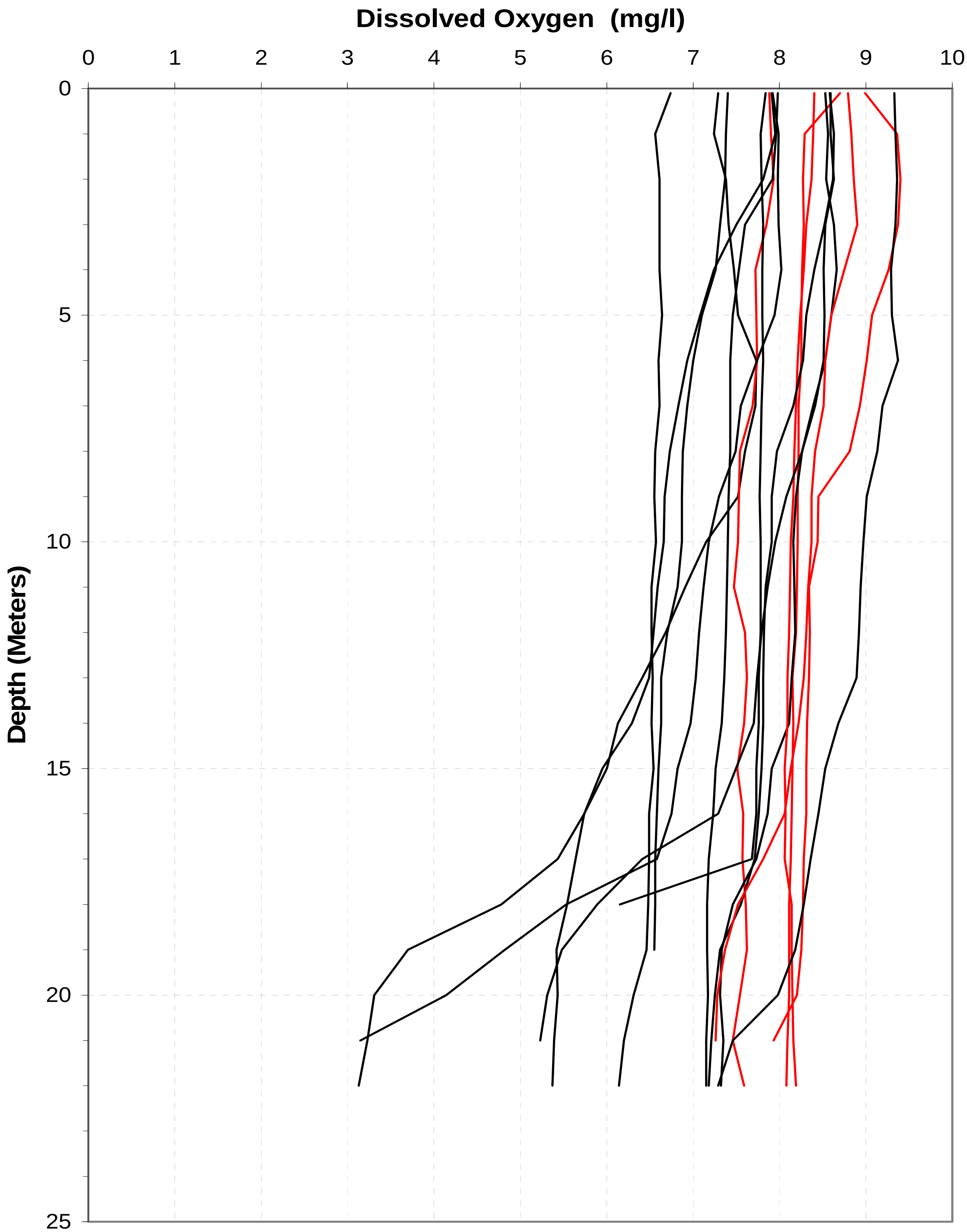


Plate 228. Dissolved oxygen depth profiles for Lake Sharpe generated from data collected at the near-dam, deepwater ambient monitoring site during the summer months of the 5-year period of 2005 through 2009.
(Note: Red profile plots were measured in the month of September.**)**

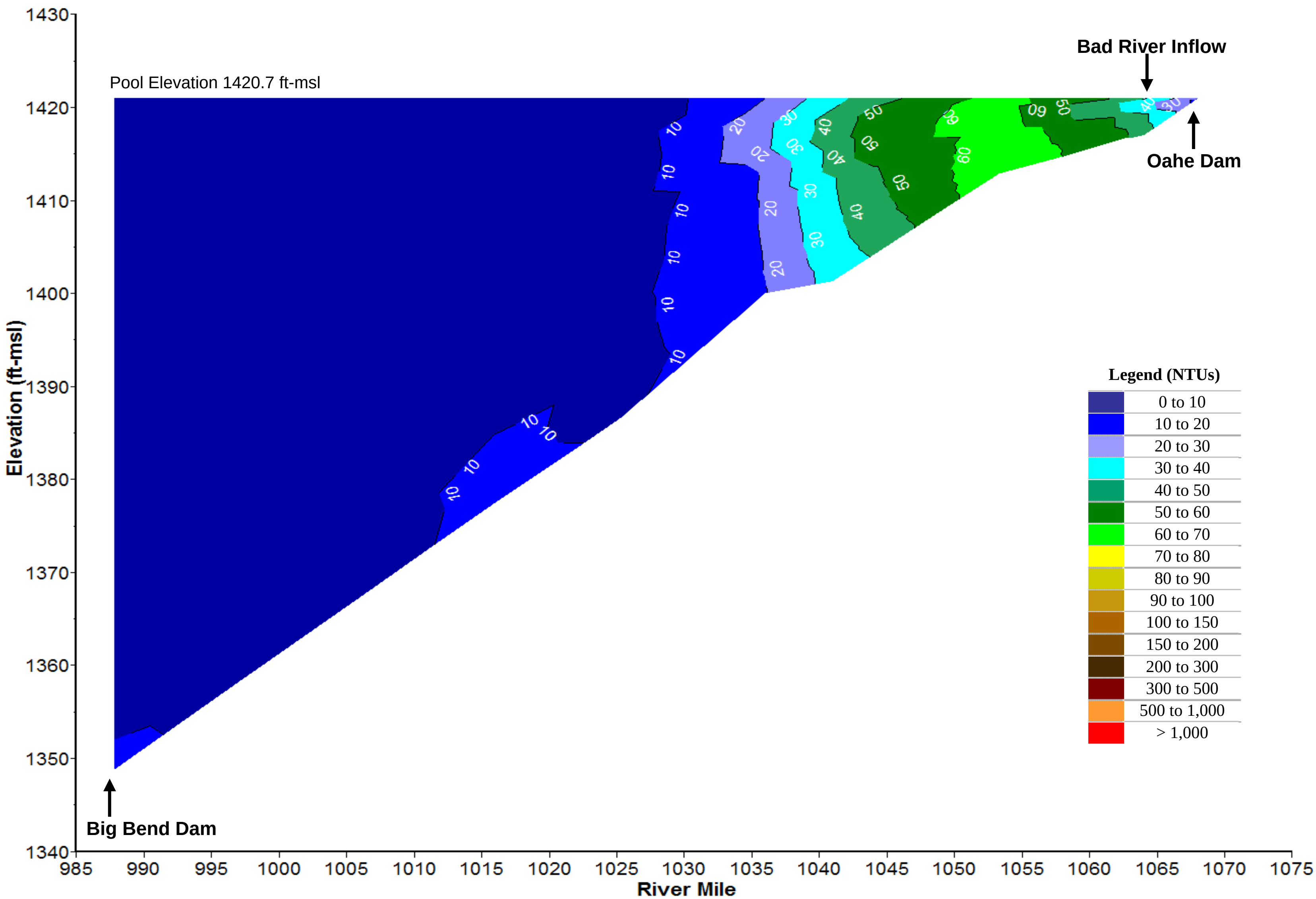


Plate 229. Longitudinal turbidity (NTU) contour plot of Lake Sharpe based on depth-profile turbidity levels measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on June 17, 2009.

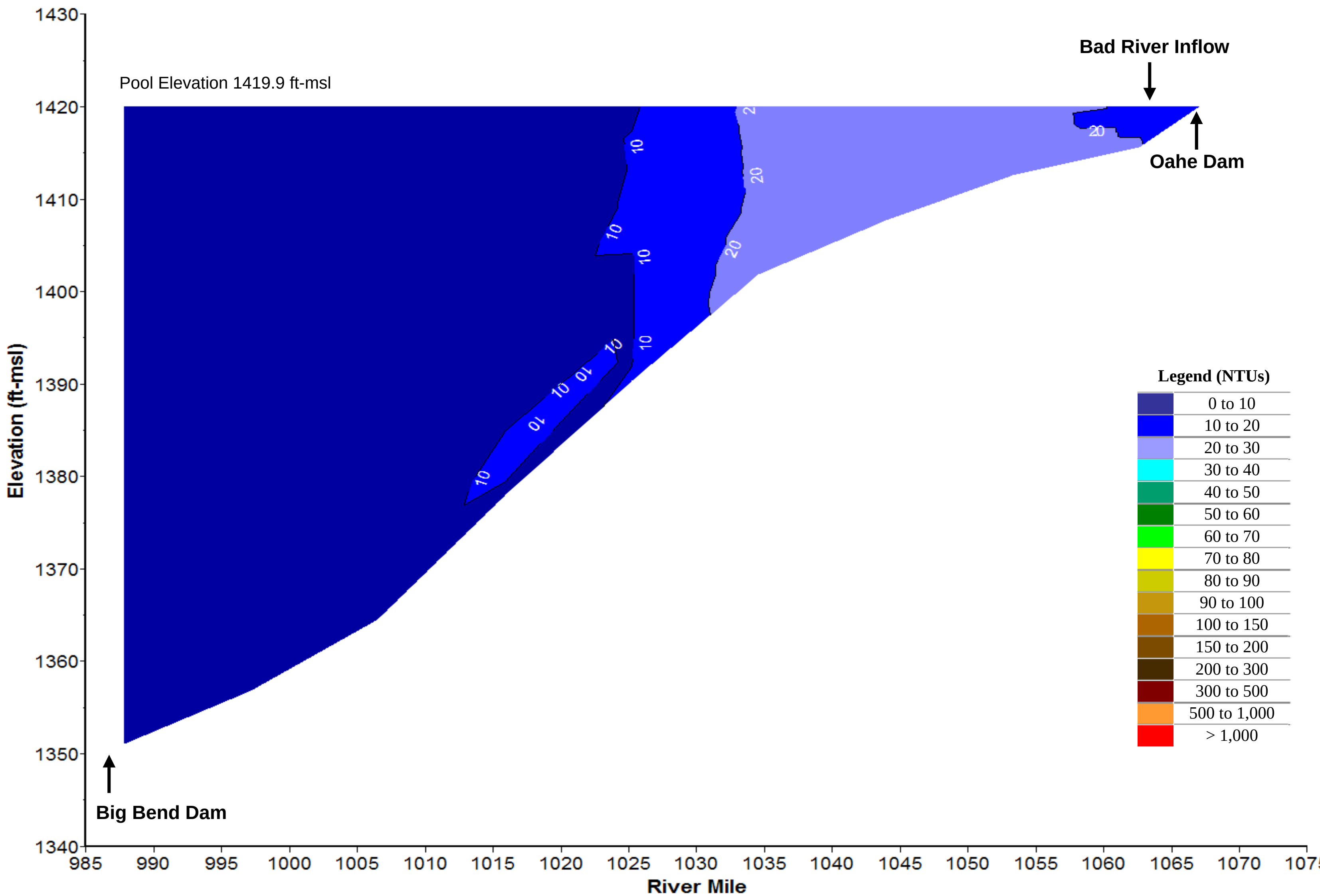


Plate 230. Longitudinal turbidity (NTU) contour plot of Lake Sharpe based on depth-profile turbidity levels measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on July 15, 2009.

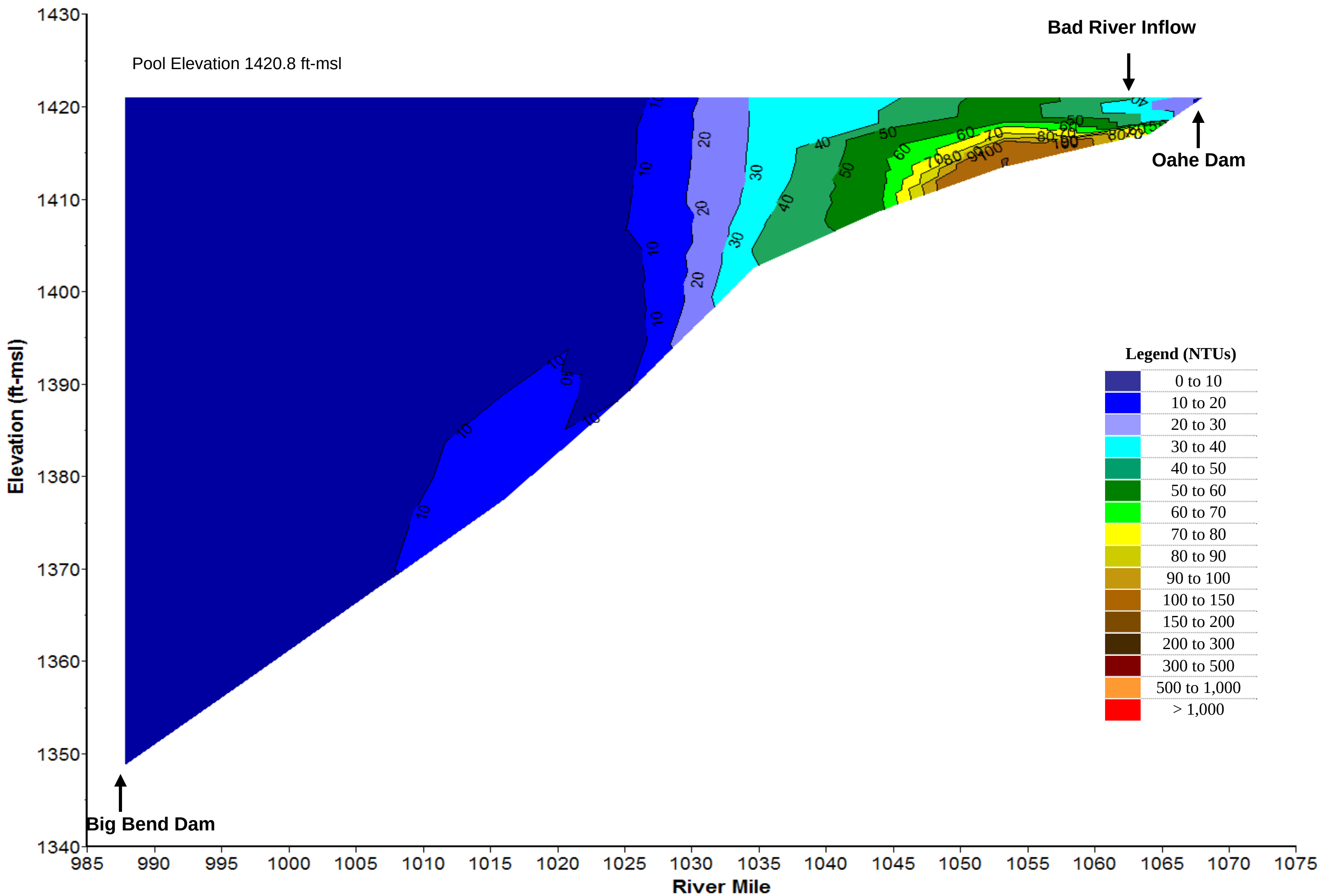


Plate 231. Longitudinal turbidity (NTU) contour plot of Lake Sharpe based on depth-profile turbidity levels measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on August 18, 2009.

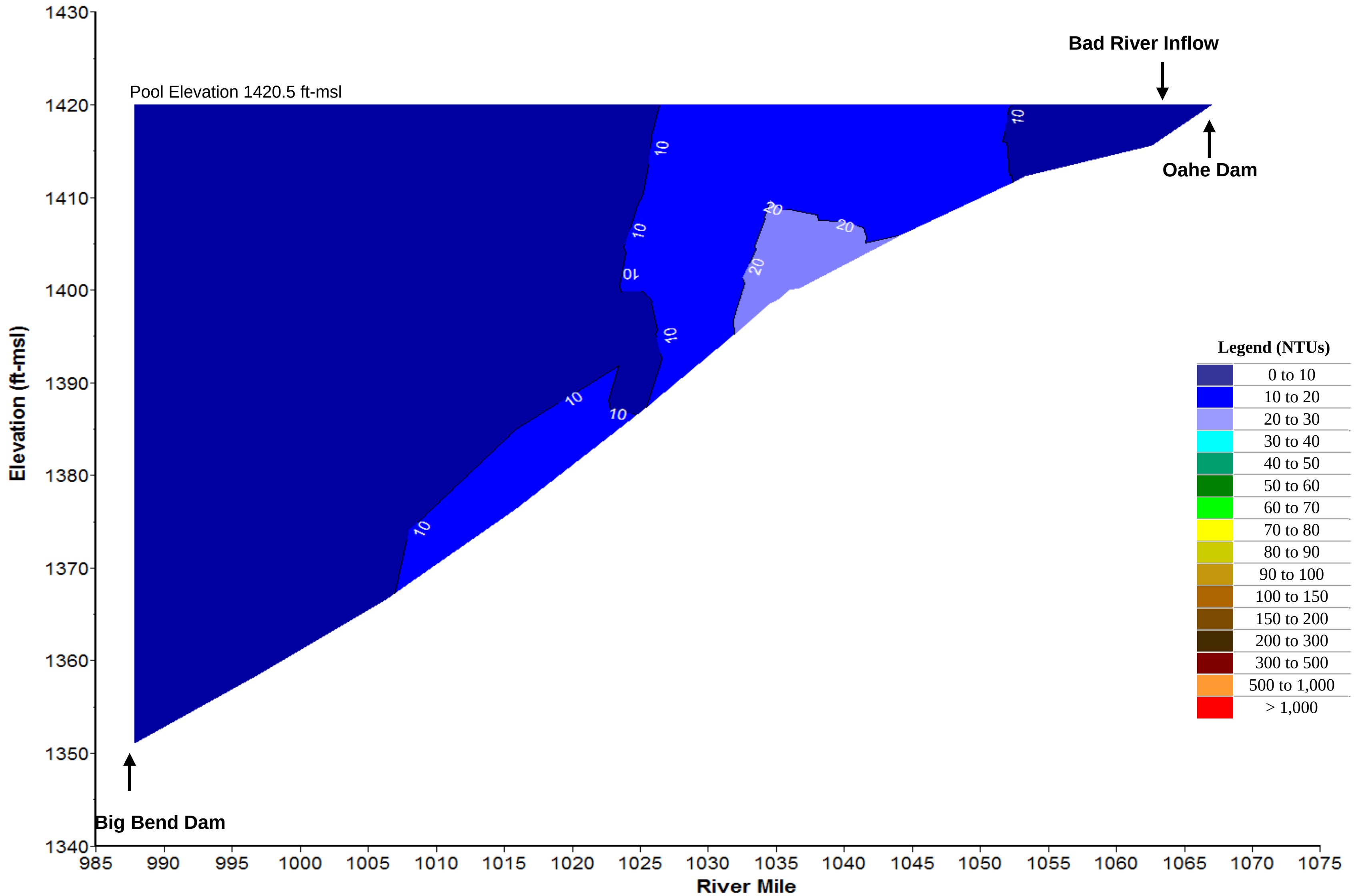


Plate 232. Longitudinal turbidity (NTU) contour plot of Lake Sharpe based on depth-profile turbidity levels measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on September 16, 2009.

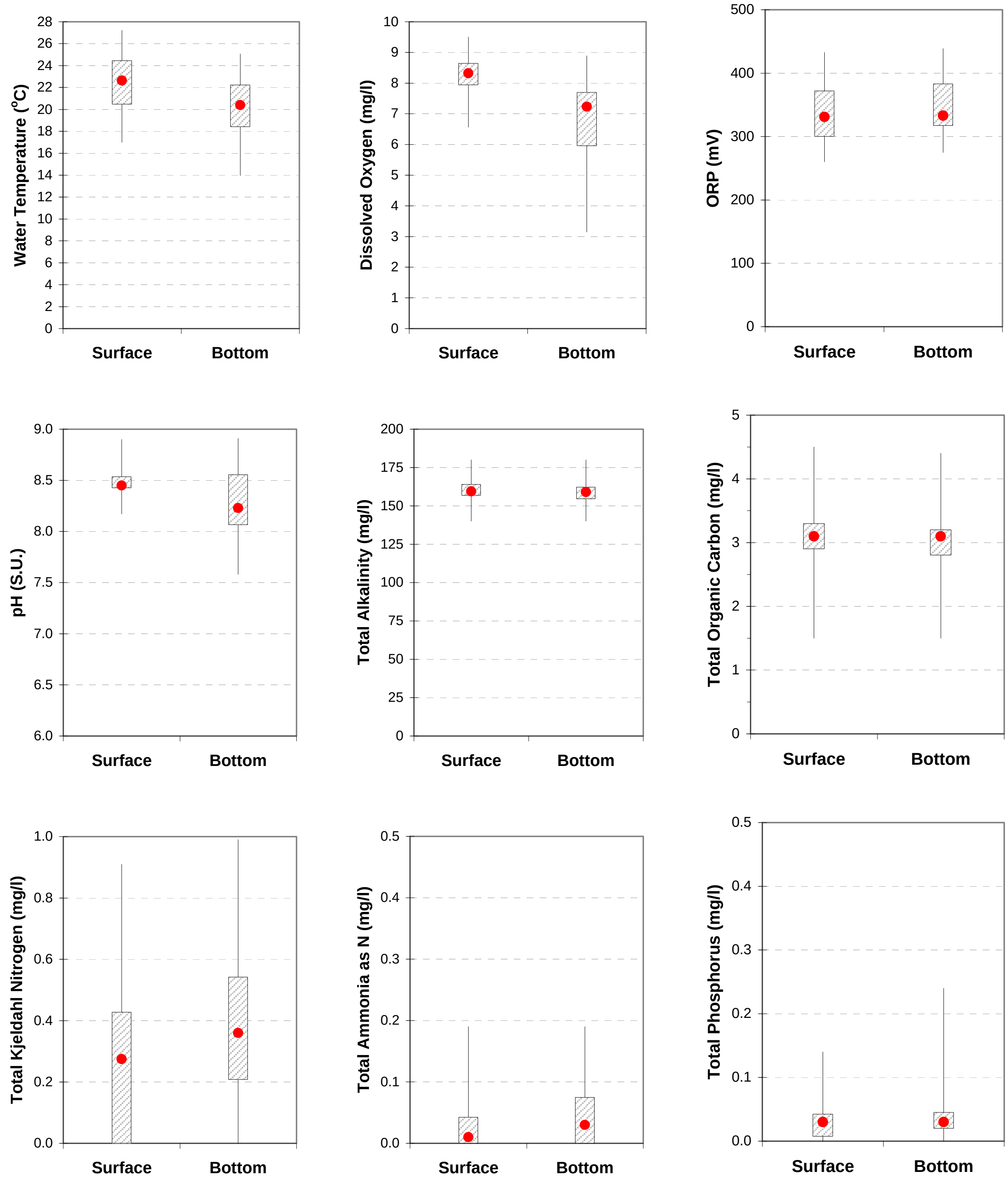


Plate 233. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Lake Sharpe at site BBDLK0987A during the summer months of 2005 through 2009.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 234. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected at the near-dam, deepwater ambient monitoring site (i.e., site BBDLK0987A) at Lake Sharpe during the 5-year period 2005 through 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
May 2005	400,458,770	6	0.93	3	<0.01	0	-----	1	0.07	1	<0.01	0	-----	0	-----	1.47
Jun 2005	12,306,159	2	0.26	1	0.04	0	-----	2	0.63	4	0.07	0	-----	0	-----	1.58
Jul 2005	223,854,976	11	0.97	2	0.01	0	-----	0	-----	1	0.01	0	-----	0	-----	1.55
Aug 2005	111,016,029	5	0.22	0	-----	2	0.26	1	0.03	8	0.48	0	-----	0	-----	2.03
Sep 2005	290,622,396	8	0.77	14	0.06	0	-----	1	0.04	5	0.12	2	<0.01	1	<0.01	1.80
May 2006	782,608,177	7	0.97	2	<0.01	0	-----	1	<0.01	0	-----	0	-----	1	0.03	0.93
Jun 2006	569,715,640	7	0.98	8	<0.01	1	<0.01	1	0.02	0	-----	0	-----	0	-----	0.16
Jul 2006	71,040,754	5	0.13	9	0.41	1	<0.01	1	0.16	3	0.14	1	0.16	0	-----	2.33
Aug 2006	460,223,040	13	0.71	14	0.15	1	0.01	1	0.01	5	0.06	3	0.06	1	0.01	2.37
Sep 2006	112,017,227	10	0.51	16	0.25	1	<0.01	1	0.05	7	0.09	2	0.09	1	<0.01	2.68
May 2007	569,470,258	9	0.95	5	0.01	0	-----	1	0.02	1	<0.01	1	0.02	0	-----	0.61
June 2007	517,899,330	5	0.74	9	0.10	1	0.13	1	0.02	1	0.01	0	-----	0	-----	1.00
July 2007	211,432,753	7	0.17	8	0.06	0	-----	2	0.13	4	0.26	1	0.38	0	-----	1.85
Aug 2007	269,806,875	10	0.20	11	0.22	1	0.03	1	0.04	4	0.42	2	0.10	0	----	2.12
Sep 2007	141,864,320	6	0.34	12	0.25	0	-----	1	0.18	7	0.15	1	0.07	0	-----	2.74
May 2008	228,544,365	12	0.97	6	0.01	0	-----	1	0.02	0	-----	1	<0.01	0	-----	1.40
Jun 2008	291,834,051	6	0.87	5	0.01	1	0.09	1	0.02	1	<0.01	1	0.01	0	-----	1.32
Jul 2008	159,849	3	0.83	2	<0.01	1	0.03	1	0.12	2	0.01	0	-----	1	0.01	0.64
Aug 2008	55,130,283	3	0.59	4	0.02	2	0.06	1	0.08	4	0.11	2	0.14	0	-----	1.52
Sep 2008	10,711,939	2	0.08	16	0.55	1	<0.01	2	<0.01	4	<0.01	3	<0.01	0	-----	1.25
May 2009	2,292,085,401	7	0.97	3	<0.01	0	-----	1	0.02	0	-----	0	-----	1	<0.01	0.34
Jun 2009	640,260,097	9	0.36	3	0.20	2	0.04	2	0.40	1	0.01	0	-----	0	-----	1.77
Jul 2009	112,486,695	12	0.39	7	0.10	1	0.02	1	0.41	2	0.01	1	0.08	0	-----	1.70
Aug 2009	100,180,903	10	0.23	9	0.19	1	0.12	1	0.25	5	0.12	2	0.10	0	-----	2.59
Sep 2009	787,509,903	7	0.33	12	0.07	2	<0.01	2	0.41	5	0.02	1	0.16	2	<0.01	1.75
Mean	**370,529,608**	**7.3**	**0.58**	**7.2**	**0.11**	**0.8**	**0.05**	**1.2**	**0.13**	**3.0**	**0.10**	**1.0**	**0.09**	**0.3**	**0.01**	**1.58**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 235. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected at the mid-lake site (i.e., site BBDLK1020DW) at Lake Sharpe during 2008 and 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2008	112,139,548	10	0.88	6	0.01	1	0.01	1	0.10	1	<0.01	0	-----	0	-----	1.61
Jul 2008	144,885	3	0.46	6	0.05	1	0.08	1	0.30	3	0.02	2	0.06	2	0.02	1.71
Aug 2008	120,710,561	7	0.41	13	0.14	0	-----	1	0.25	7	0.02	2	0.08	2	0.10	2.07
Sep 2008	55,048,141	7	0.41	6	0.21	0	-----	2	0.37	1	<0.01	1	<0.01	0	-----	1.77
Jun 2009	2,476,477,216	6	0.98	2	<0.01	1	<0.01	1	0.02	0	-----	1	<0.01	0	-----	0.37
Jul 2009	2,008,568,663	13	0.94	8	0.01	1	<0.01	2	0.05	1	<0.01	1	<0.01	3	<0.01	0.85
Aug 2009	1,706,722,089	11	0.83	15	0.08	1	<0.01	1	0.05	4	<0.01	2	0.03	3	<0.01	1.43
Sep 2009	1,404,112,611	11	0.67	10	0.05	2	0.05	2	0.20	3	0.01	1	0.02	0	-----	2.17
Mean	**985,490,464**	**8.5**	**0.70**	**8.3**	**0.07**	**0.9**	**0.02**	**1.4**	**0.17**	**2.5**	**0.01**	**1.3**	**0.03**	**1.3**	**0.03**	**1.50**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 236. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in the upstream reaches of Lake Sharpe (i.e., site BBDLK1055DW) during 2008 and 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2008	111,255,352	13	0.96	0	-----	0	-----	1	0.04	0	-----	0	-----	0	-----	2.03
Jul 2008	63,807	7	0.27	4	0.04	1	0.05	1	0.45	0	-----	2	0.18	0	-----	1.57
Aug 2008	43,271,250	9	0.82	1	0.01	1	0.06	1	0.05	2	<0.01	1	0.06	0	-----	1.56
Sep 2008	204,098,336	13	0.86	3	0.02	0	-----	2	0.02	2	0.01	1	0.09	0	-----	1.57
Jun 2009	176,681,625	17	0.95	0	-----	0	-----	1	0.05	1	<0.01	0	-----	0	-----	1.29
Jul 2009	316,282,450	16	0.95	5	0.04	0	-----	1	0.01	0	-----	0	-----	0	-----	1.59
Aug 2009	39,379,179	13	0.90	3	0.04	0	-----	1	0.05	1	0.01	0	-----	0	-----	1.92
Sep 2009	852,519,419	15	0.79	5	0.03	1	<0.01	2	0.18	1	<0.01	0	-----	0	-----	1.67
Mean	**217,943,927**	**12.9**	**0.81**	**2.6**	**0.03**	**0.4**	**0.04**	**1.3**	**0.11**	**0.9**	**<0.01**	**0.05**	**0.11**	**0**	**-----**	**1.65**

* Mean percent composition represents the mean when taxa of that division are present.

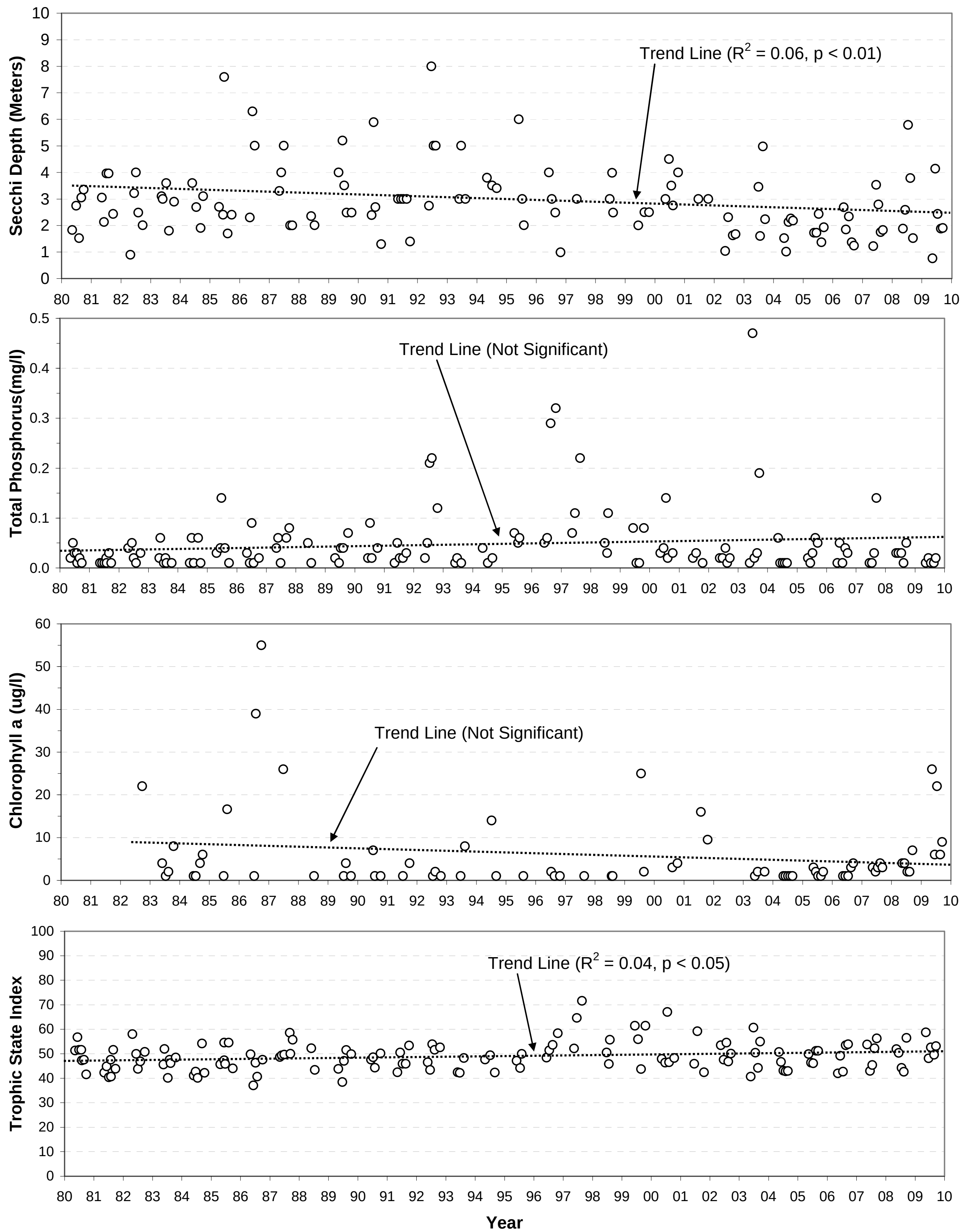


Plate 237. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Lake Sharpe at the near-dam, ambient site (i.e., site BBDLK0987A) over the 29-year period of 1980 through 2009.

Plate 238. Summary of water quality conditions monitored in the Bad River at site BBDNFBADR1 during the 2-year period 2008 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Flow (cfs)	1	9	428	7	<1	3,760	-----	-----	-----
Water Temperature (°C)	0.1	7	20.1	20.1	15.6	24.6	27(1,4)	0	0%
Dissolved Oxygen (mg/l)	0.1	7	9.9	9.2	6.8	17.0	5(1,5)	1	2%
Dissolved Oxygen (% Sat.)	0.1	7	106.7	108.2	78.2	145.2	-----	-----	-----
pH (S.U.)	0.1	6	8.1	8.1	7.9	8.5	6.5(1,2,5), 9.0(1,2,4), 9.5(3,4)	0	0%
Specific Conductance (umho/cm)	1	7	884	755	378	1,745	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	7	351	322	268	552	-----	-----	-----
Turbidity (NTU)	1	7	206	10	2	1,359	-----	-----	-----
Alkalinity, Total (mg/l)	7	9	149	159	116	165	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	9	5.1	3.7	2.5	10.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	9	21	10	6	82	-----	-----	-----
Chloride, Dissolved (mg/l)	1	9	22	13	9	74	175(1,4), 100(1,6), 438(2,4), 250(2,6)	0	0%
Dissolved Solids, Total (mg/l)	5	9	674	616	460	1,226	1,750(2,4), 1,000(2,7), 3,500(3,4), 2,000(3,6)	0, 1, 0, 0	0%, 11%, 0%, 0%
Iron, Total (ug/l)	40	7	13,710	310	210	93,000	-----	-----	-----
Manganese, Total (ug/l)	2	7	761	30	20	5,060	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	9	-----	0.03	n.d.	0.34	7.0 (1,4,7), 1.4(1,6,7)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	9	1.0	0.9	0.3	3.3	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	9	-----	0.04	n.d.	0.40	10(2,4)	0	0%
Nitrogen, Total (mg/l)	0.1	9	1.1	0.9	0.3	3.7	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	9	-----	0.02	n.d.	0.05	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	9	0.36	0.04	n.d.	2.90	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	9	-----	n.d.	n.d.	0.05	-----	-----	-----
Sulfate (mg/l)	1	9	283	225	135	630	875(2,4), 500(2,6)	0, 1	0%, 11%
Suspended Solids, Total (mg/l)	4	9	-----	6	n.d.	3,478	158(1,4), 90(1,6)	1, 1	11%, 11%
Pesticide Scan (ug/l)(D)	0.05	1	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected, b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of warmwater permanent fish life propagation waters.

(2) Criteria for the protection of domestic water supply waters.

(3) Criteria for the protection of commerce and industry waters.

(4) Daily maximum criterion (monitoring results directly comparable to criterion).

(5) Daily minimum criterion (monitoring results directly comparable to criterion).

(6) 30-day average criterion (monitoring results not directly comparable to criterion).

(7) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

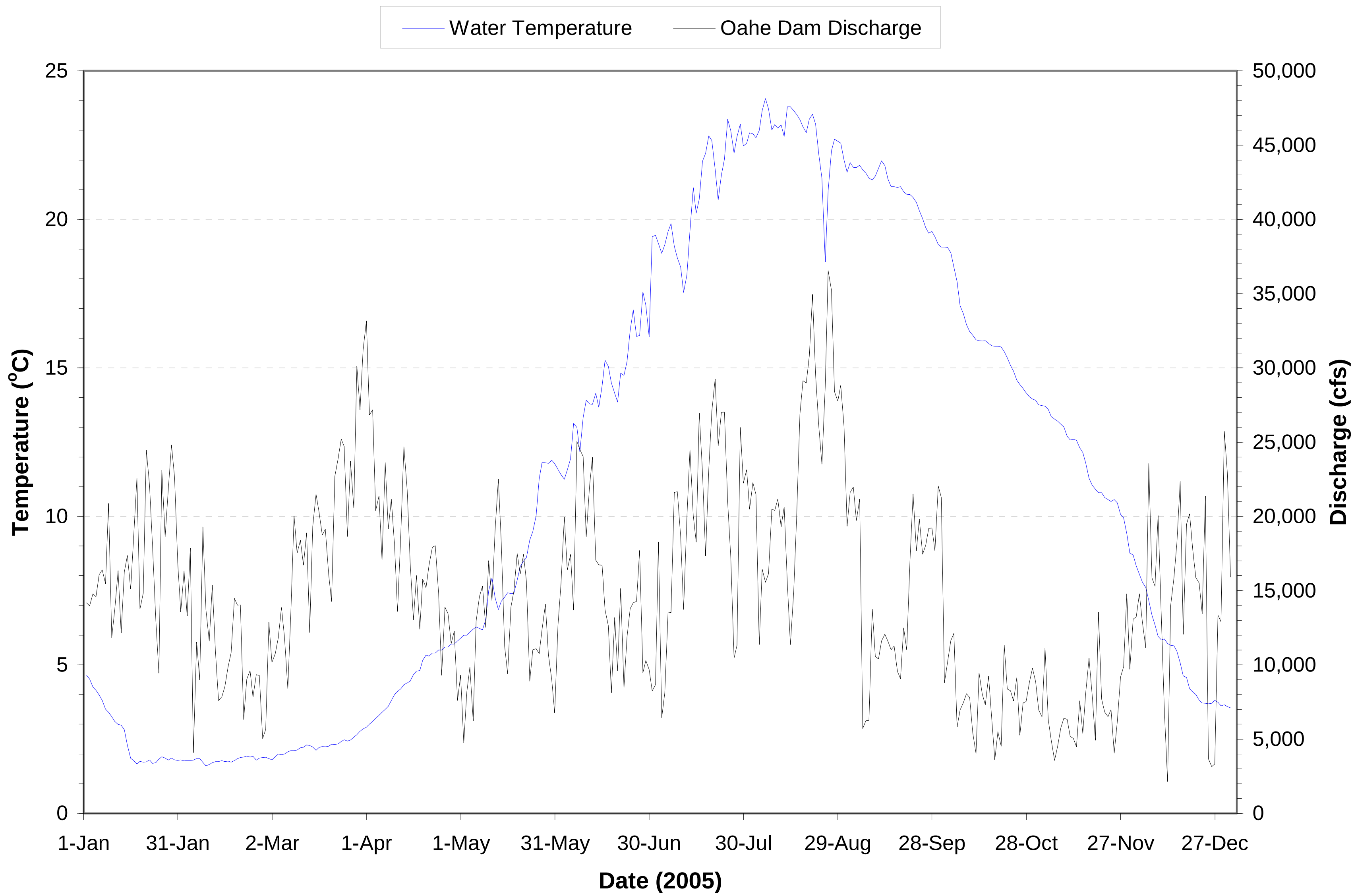


Plate 239. Mean daily water temperature and discharge of the Missouri River at Oahe Dam (i.e., site OAHPP1) for 2005. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Oahe Dam.

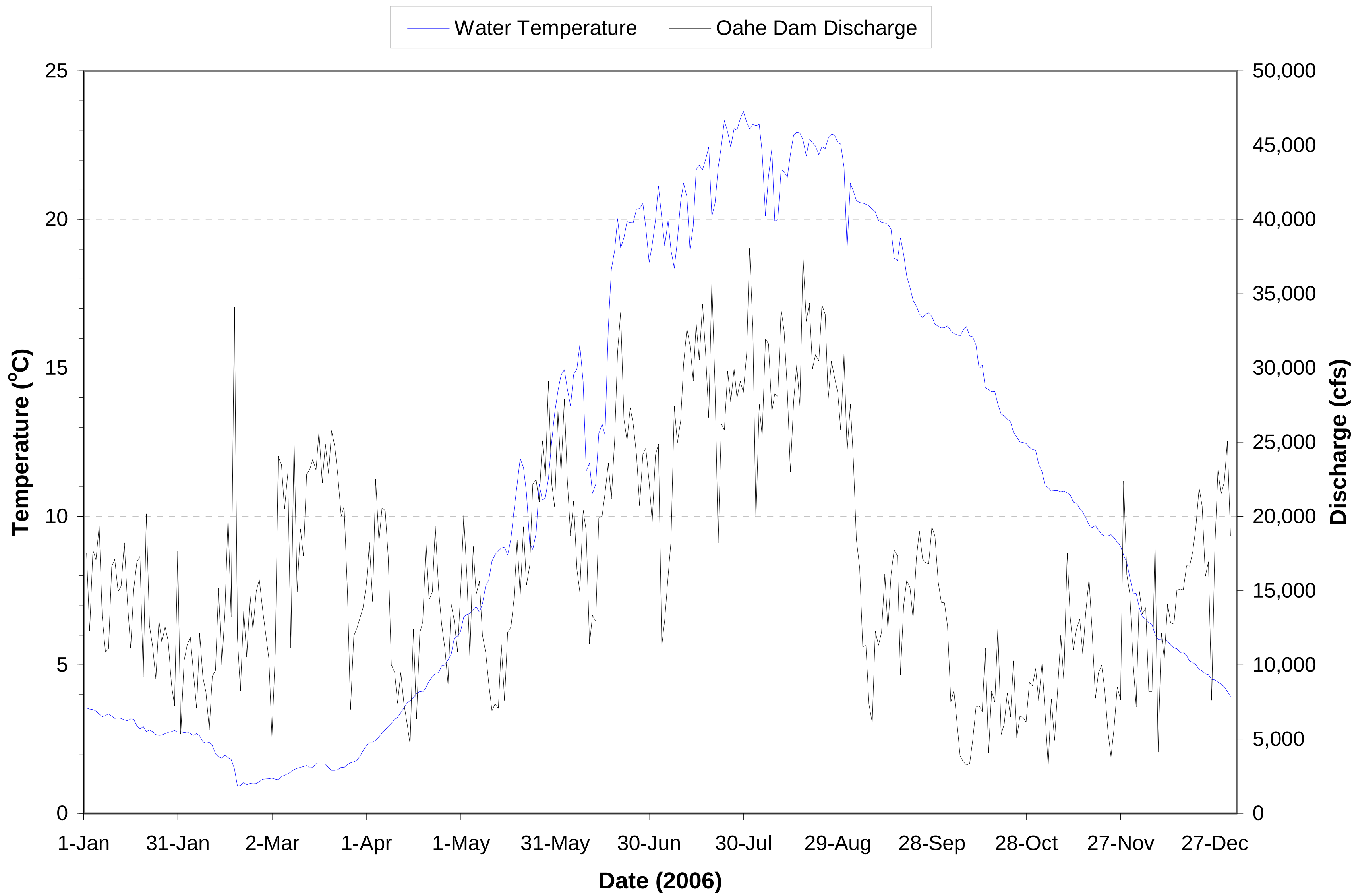


Plate 240. Mean daily water temperature and discharge of the Missouri River at Oahe Dam (i.e., site OAHPP1) for 2006. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Oahe Dam.

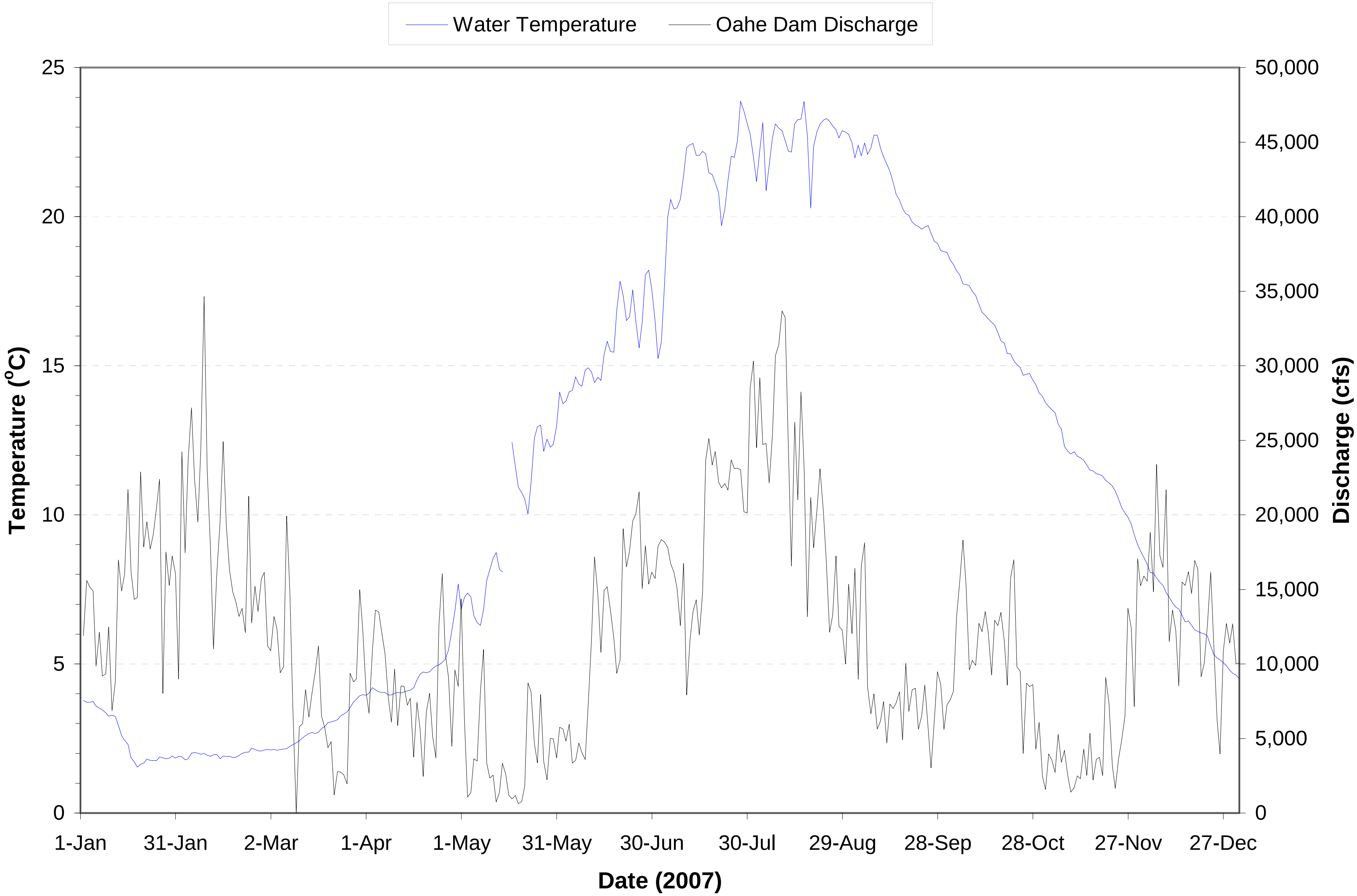


Plate 241. Mean daily water temperature and discharge of the Missouri River at Oahe Dam (i.e., site OAHPP1) for 2007. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Oahe Dam.

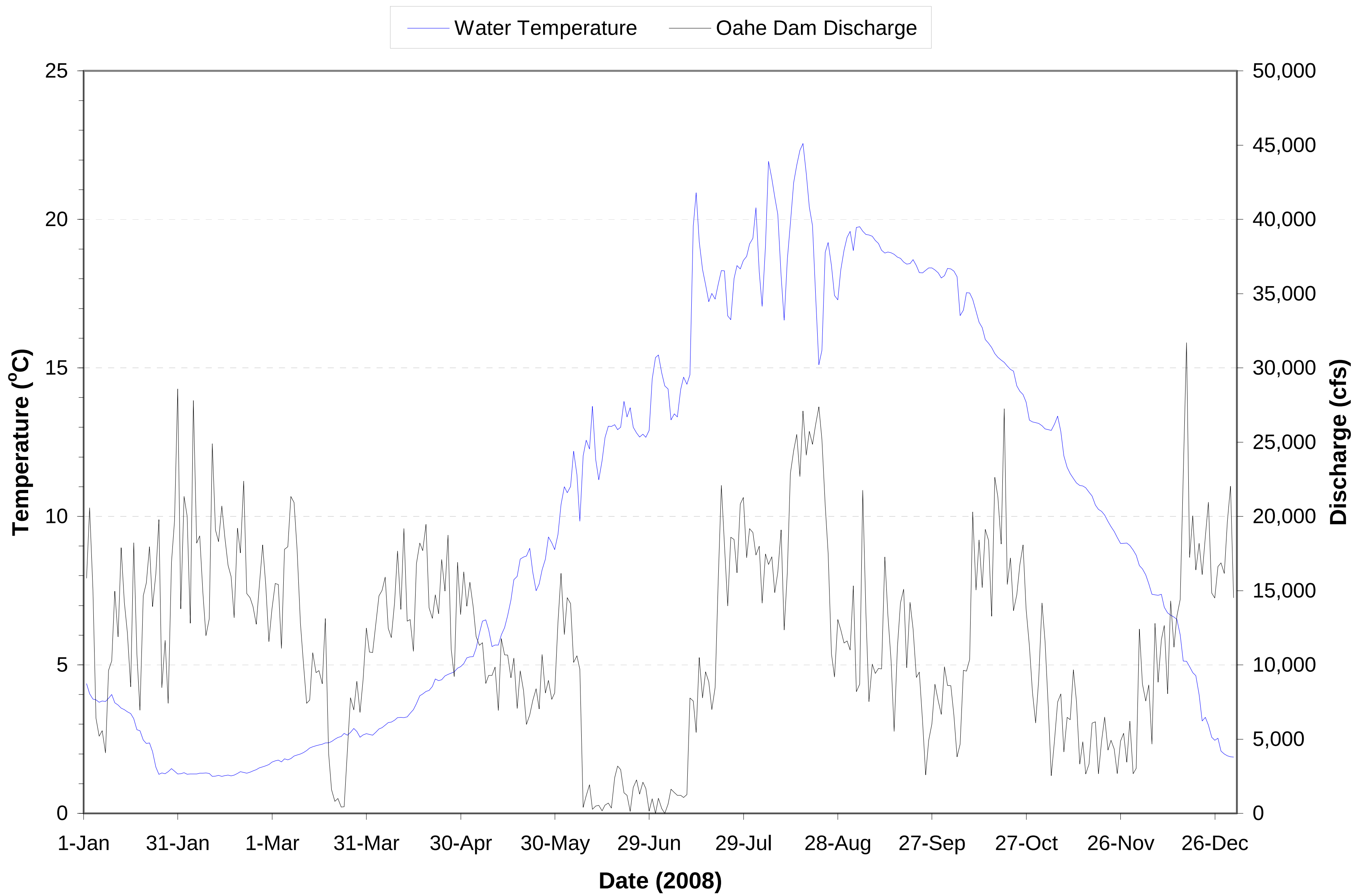


Plate 242. Mean daily water temperature and discharge of the Missouri River at Oahe Dam (i.e., site OAHPP1) for 2008. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Oahe Dam.

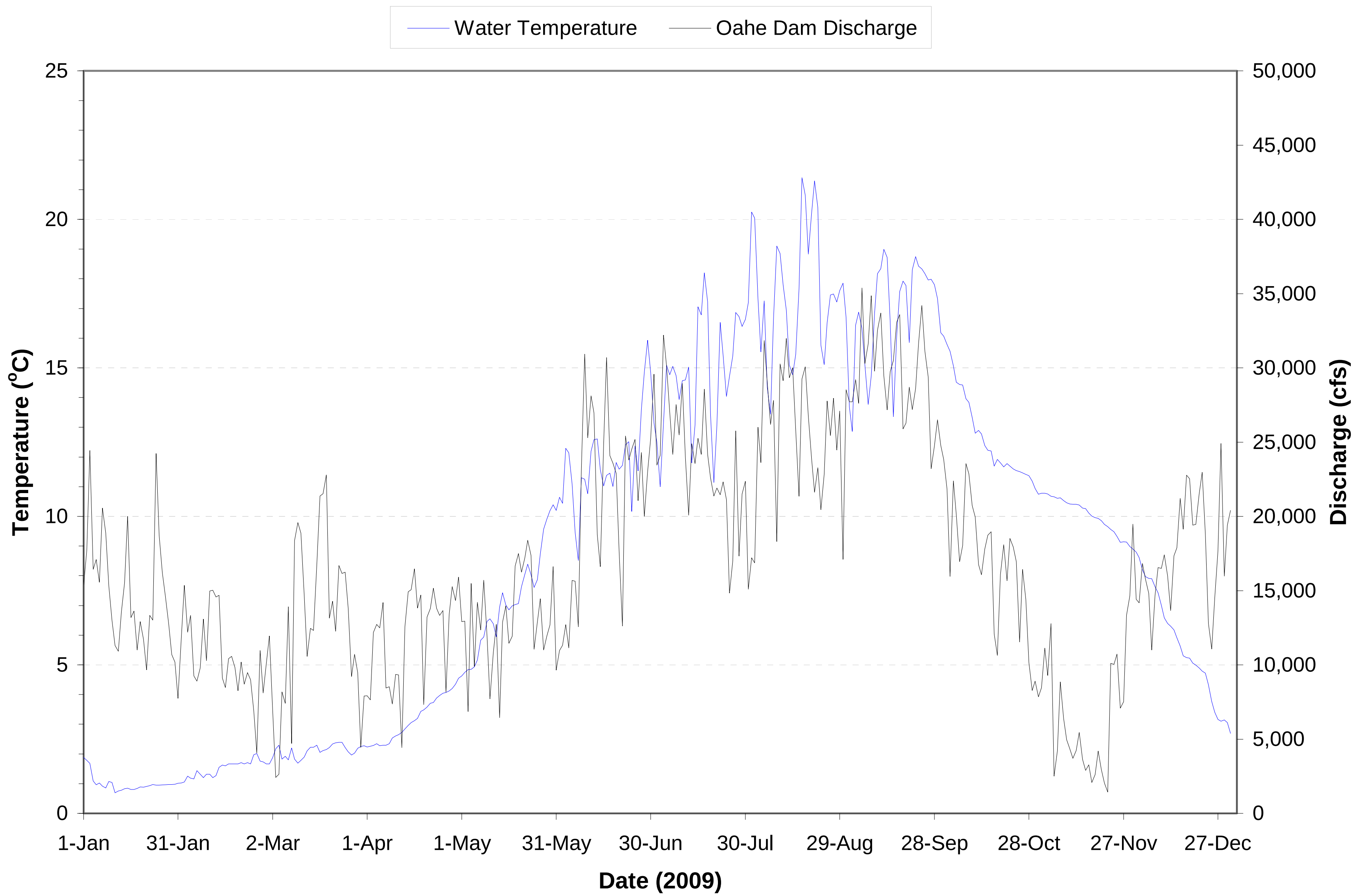


Plate 243. Mean daily water temperature and discharge of the Missouri River at Oahe Dam (i.e., site OAHPP1) for 2009. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Oahe Dam.

Plate 244. Summary of water quality conditions monitored on water discharged through Big Bend Dam (i.e., site BBDPP1) during the 5-year period of 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[(A)]	No. of Obs.	Mean[(B)]	Median	Min.	Max.	State WQS Criteria[(C)]	No. of WQS Exceedances	Percent WQS Exceedance
Dam Discharge (cfs)	1	51	25,568	23,271	0	71,980	-----	-----	-----
Water Temperature (°C)	0.1	49	12.2	11.0	0.5	25.4	27[(1,2)]	0	0%
Dissolved Oxygen (mg/l)	0.1	48	9.8	9.7	3.8	15.0	5[(1,3)]	1	2%
Dissolved Oxygen (% Sat.)	0.1	48	91.6	94.0	44.7	113.9	-----	-----	-----
pH (S.U.)	0.1	47	8.3	8.3	7.4	8.7	6.5[(1,3)], 9.0[(1,2)]	0	0%
Specific Conductance (umho/cm)	1	48	695	699	598	789	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	32	362	357	243	489	-----	-----	-----
Turbidity (NTU)	1	32	-----	3	n.d.	60	-----	-----	-----
Alkalinity, Total (mg/l)	7	51	167	163	140	195	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	50	3.2	3.1	1.4	5.6	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	41	10	10	n.d.	21	-----	-----	-----
Chloride, Dissolved (mg/l)	1	39	12	12	9	25	438[(2,4)], 250[(2,6)]	0	0%
Dissolved Solids, Total (mg/l)	5	51	482	472	380	753	1,750[(2,4)], 1,000[(2,7)], 3,500[(3,4)], 2,000[(3,6)]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	51	-----	0.03	n.d.	0.31	4.7 [(1,4,7)], 1.4 [(1,6,7)]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	51	0.5	0.4	n.d.	1.7	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	51	-----	n.d.	n.d.	0.40	10[(2,4)]	0	0%
Nitrogen, Total (mg/l)	0.1	51	0. 6	0.4	n.d.	1.7			
Phosphorus, Dissolved (mg/l)	0.02	39	-----	n.d.	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	51	-----	0.03	n.d.	0.15	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	50	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	51	202	206	172	237	875[(2,4)], 500[(2,6)]	0	0%
Suspended Solids, Total (mg/l)	4	51	-----	n.d.	n.d.	57	158[(1,4)], 90[(1,6)]	0	0%

n.d. = Not detected, b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of commerce and industry waters.
- (4) Daily maximum criterion (monitoring results directly comparable to criterion).
- (5) Daily minimum criterion (monitoring results directly comparable to criterion).
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

Plate 245. Summary of annual metals and pesticide levels monitored on water discharged through Big Bend Dam (i.e., site BBDPP1) during the 5-year period of 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Aluminum, Total (ug/l)	25	3	172	190	127	200	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	0.6	-----	-----	-----
Antimony, Total (ug/l)	0.5	3	-----	n.d.	n.d.	0.7	5.6[3]	0	0%
Arsenic, Dissolved (ug/l)	1	4	-----	1	n.d.	2	340[1], 150[2]	0, 0	0%, 0%
Arsenic, Total (ug/l)	1	3	2	2	2	2	0.018[3]	3	100%
Barium, Dissolved (ug/l)	5	3	44	44	41	46	-----	-----	-----
Barium, Total (ug/l)	5	3	47	50	41	52	-----	-----	-----
Beryllium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Beryllium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	4[3]	0	0%
Cadmium, Dissolved (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	4.3[1], 0.42[2]	0	0%
Cadmium, Total (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	5[3]	0	0%
Chromium, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	n.d.	1,075[1], 140[2]	0	0%
Chromium, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Copper, Dissolved (ug/l)	2	7	-----	n.d.	n.d.	n.d.	28[1], 17[2],	0	0%
Copper, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	1,300[3]	0	0%
Hardness, Total (mg/l)	0.4	4	210	217	169	238	-----	-----	-----
Iron, Dissolved (ug/l)	40	25[A]	-----	n.d.	n.d.	142	-----	-----	-----
Iron, Total (ug/l)	40	25[A]	167	146	n.d.	553	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	148[1], 5.8[2]	0	0%
Lead, Total (ug/l)	0.5	3	-----	n.d.	n.d.	0.5	-----	-----	-----
Manganese, Dissolved (ug/l)	2	24[A]	-----	2	n.d.	53	-----	-----	-----
Manganese, Total (ug/l)	2	25[A]	46	40	n.d.	178	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	8	-----	n.d.	n.d.	n.d.	1.4[1]	0	0%
Mercury, Total (ug/l)	0.05	8	-----	n.d.	n.d.	n.d.	0.77[2], 0.05[3]	0	0%
Nickel, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	n.d.	902[1], 100[2]	0	0%
Nickel, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	610[3]	0	0%
Selenium, Total (ug/l)	1	3	2	2	1	2	4.6[2], 170[3]	0	0%
Silver, Dissolved (ug/l)	1	7	-----	n.d.	n.d.	n.d.	12[1]	0	0%
Silver, Total (ug/l)	1	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Total (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	0.24[3]	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	11	226[1,2]	0	0%
Zinc, Total (ug/l)	10	3	-----	13	n.d.	50	7,400[3]	0	0%
Pesticide Scan (ug/l)[D]	0.05	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected, b.d. = Criterion below detection limit.

(A) Results for iron (dissolved and total) and manganese (dissolved and total) include some monthly samples.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Acute (CMC) criterion for the protection of freshwater aquatic life.

(2) Chronic (CCC) criterion for the protection of freshwater aquatic life.

(3) Criterion for the protection of human health.

Note: Some of South Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

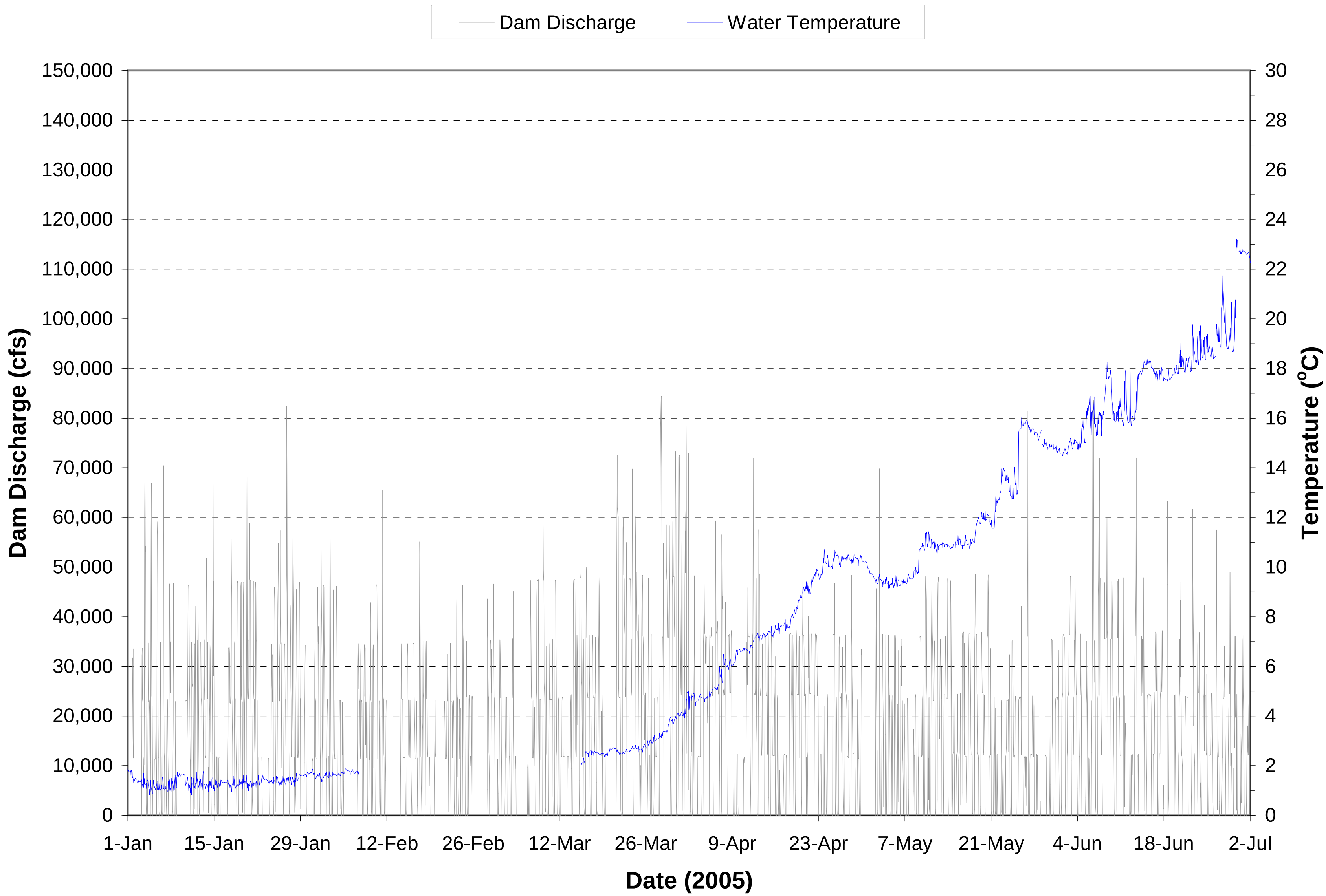


Plate 246. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2005.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

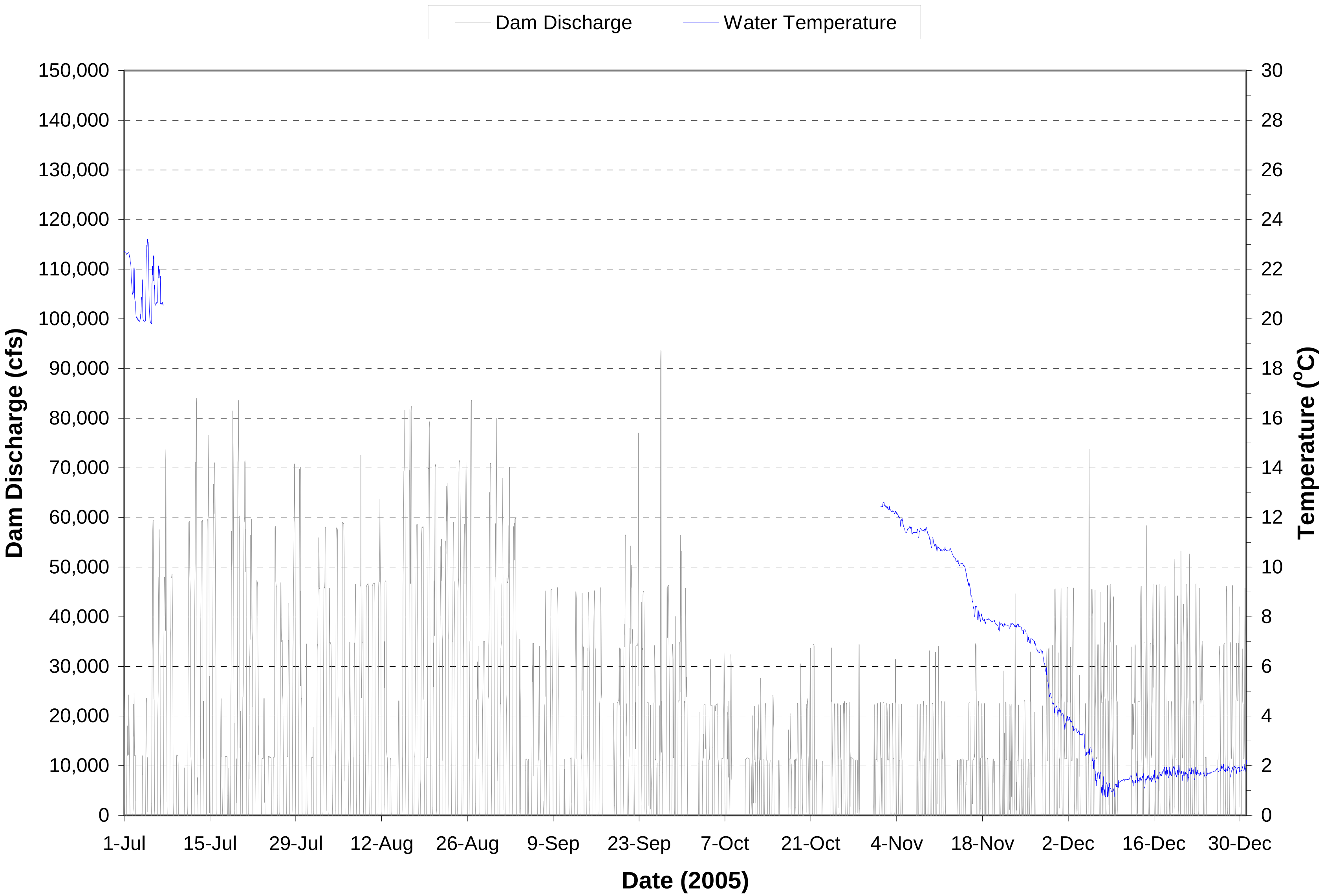


Plate 247. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2005.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

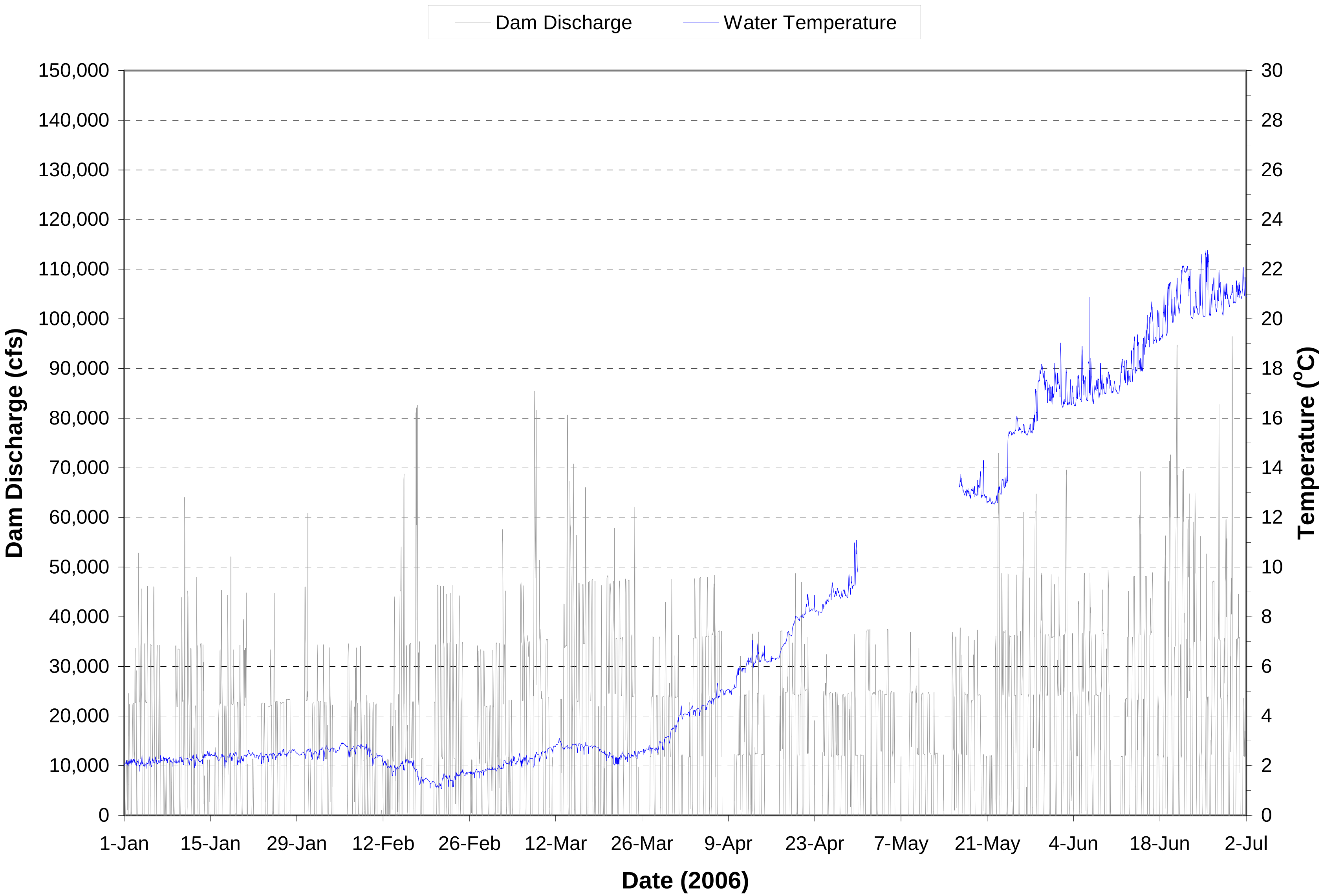


Plate 248. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

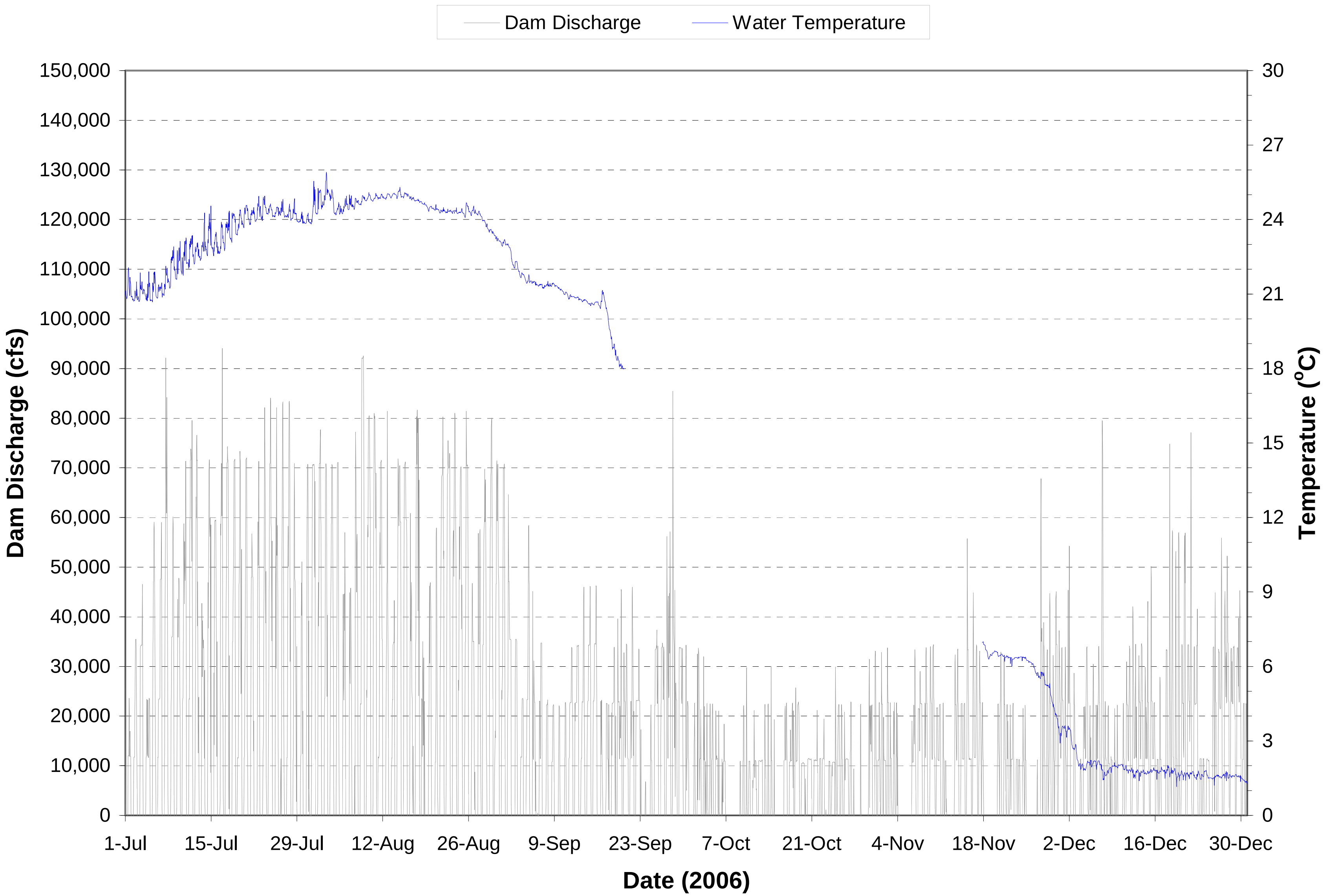


Plate 249. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

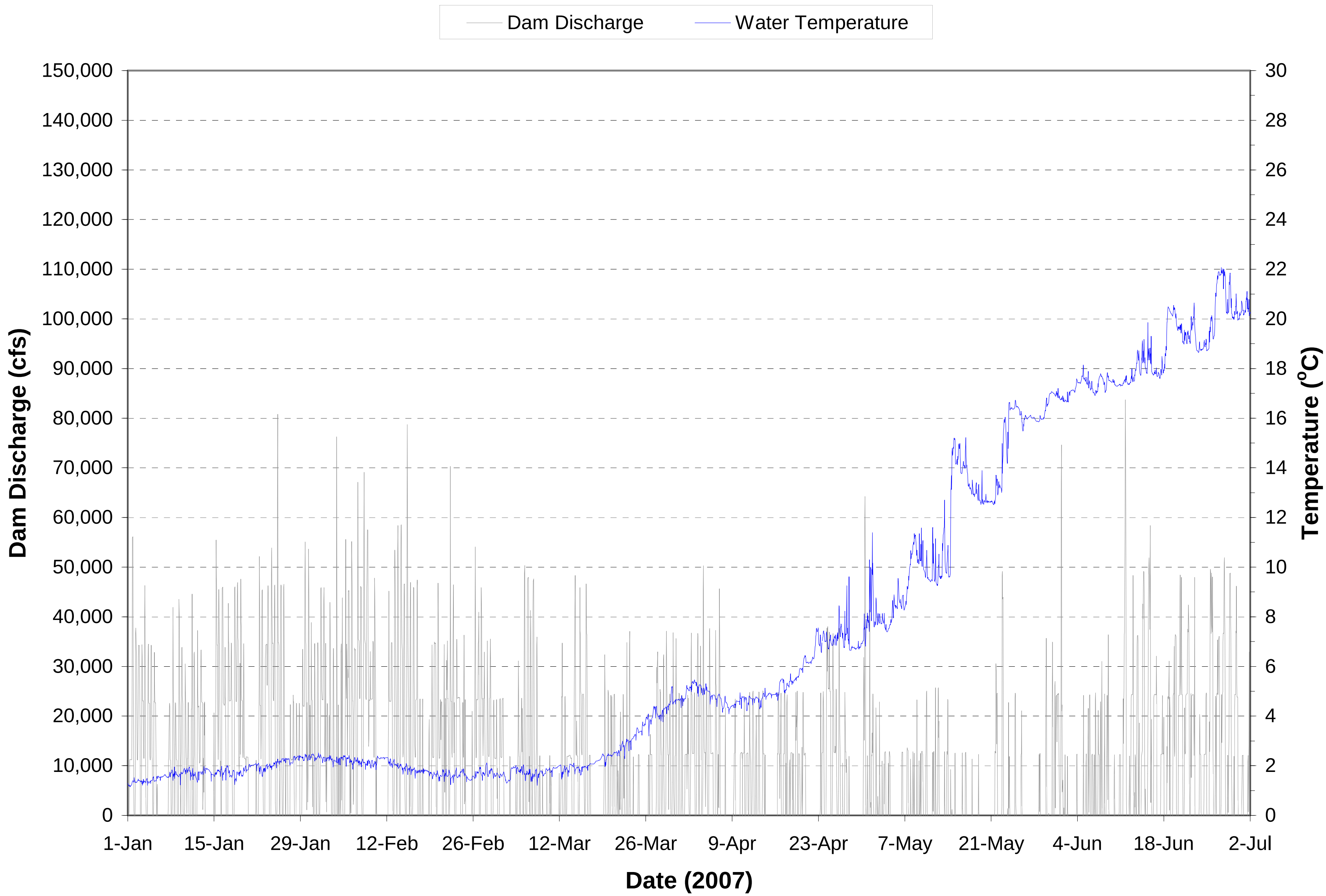


Plate 250. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2007.

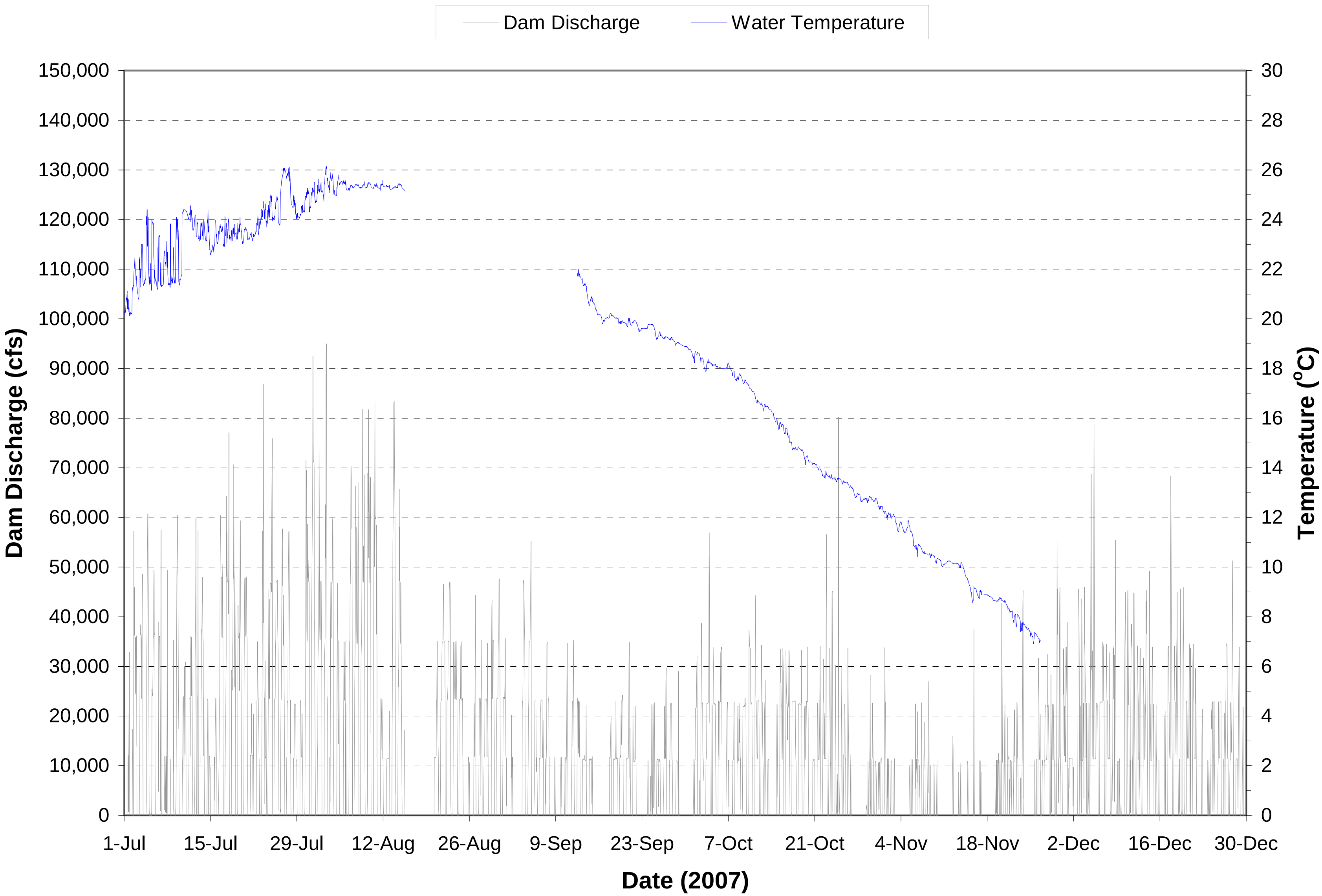


Plate 251. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

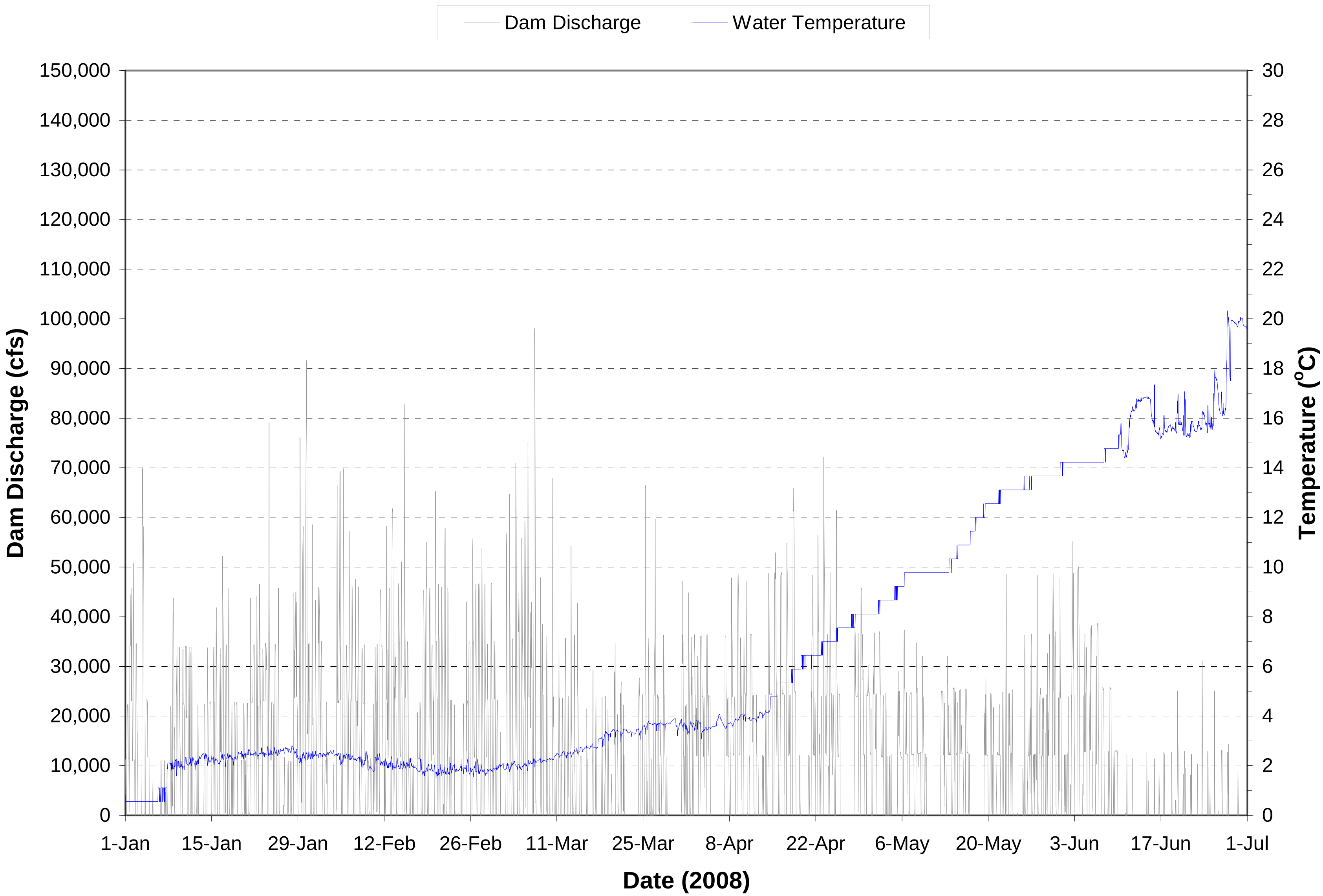


Plate 252. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2008.

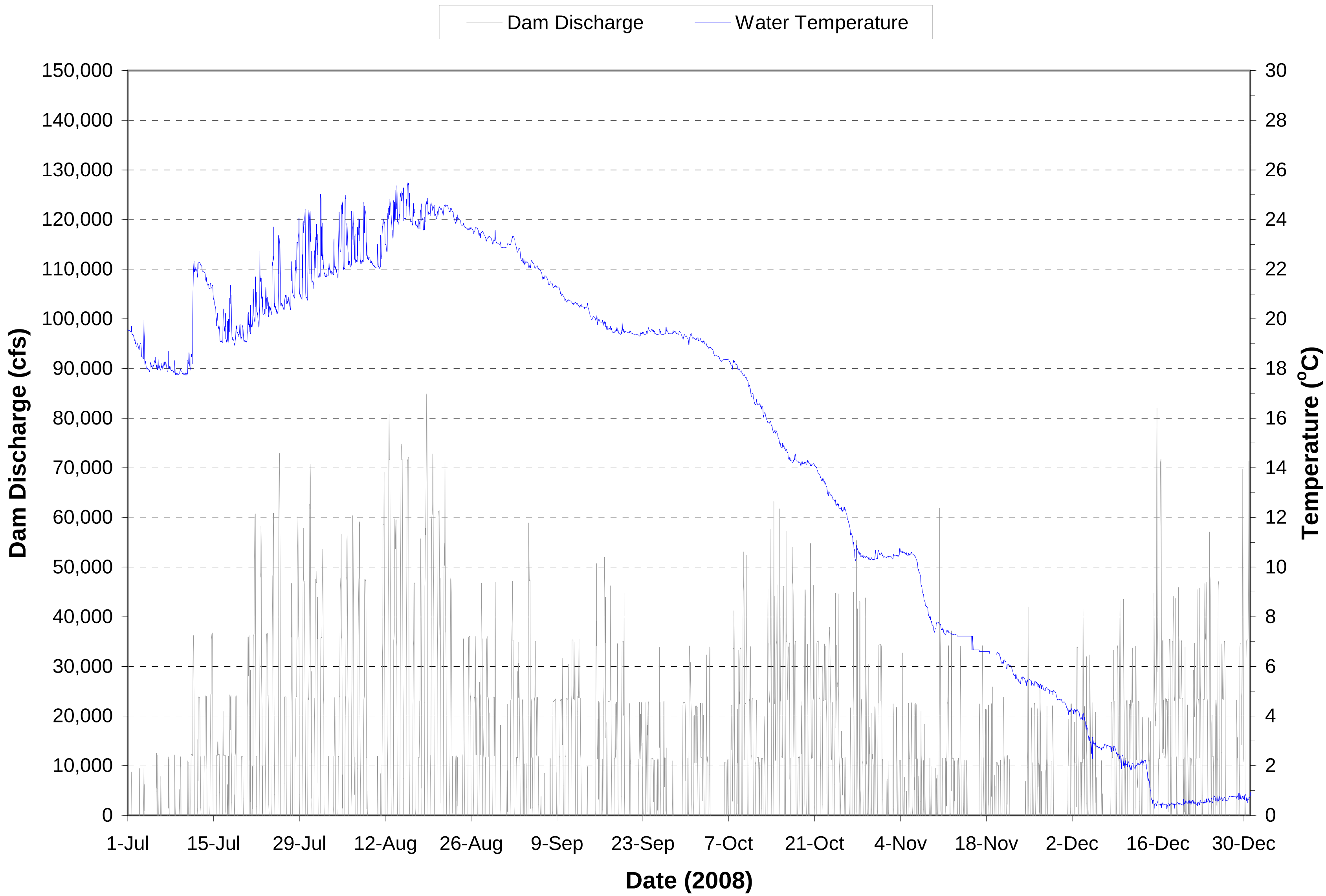


Plate 253. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2008.

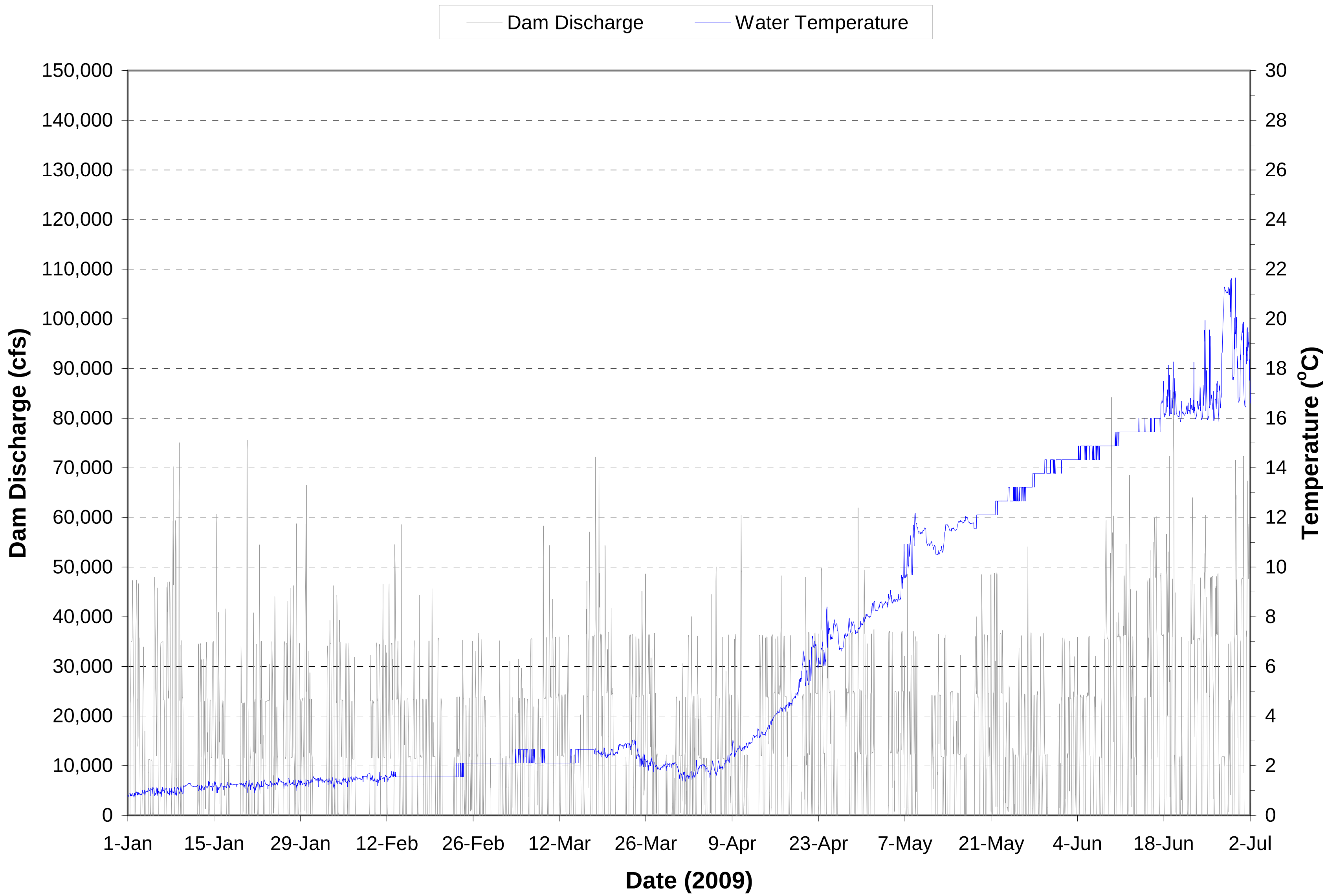


Plate 254. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2009.

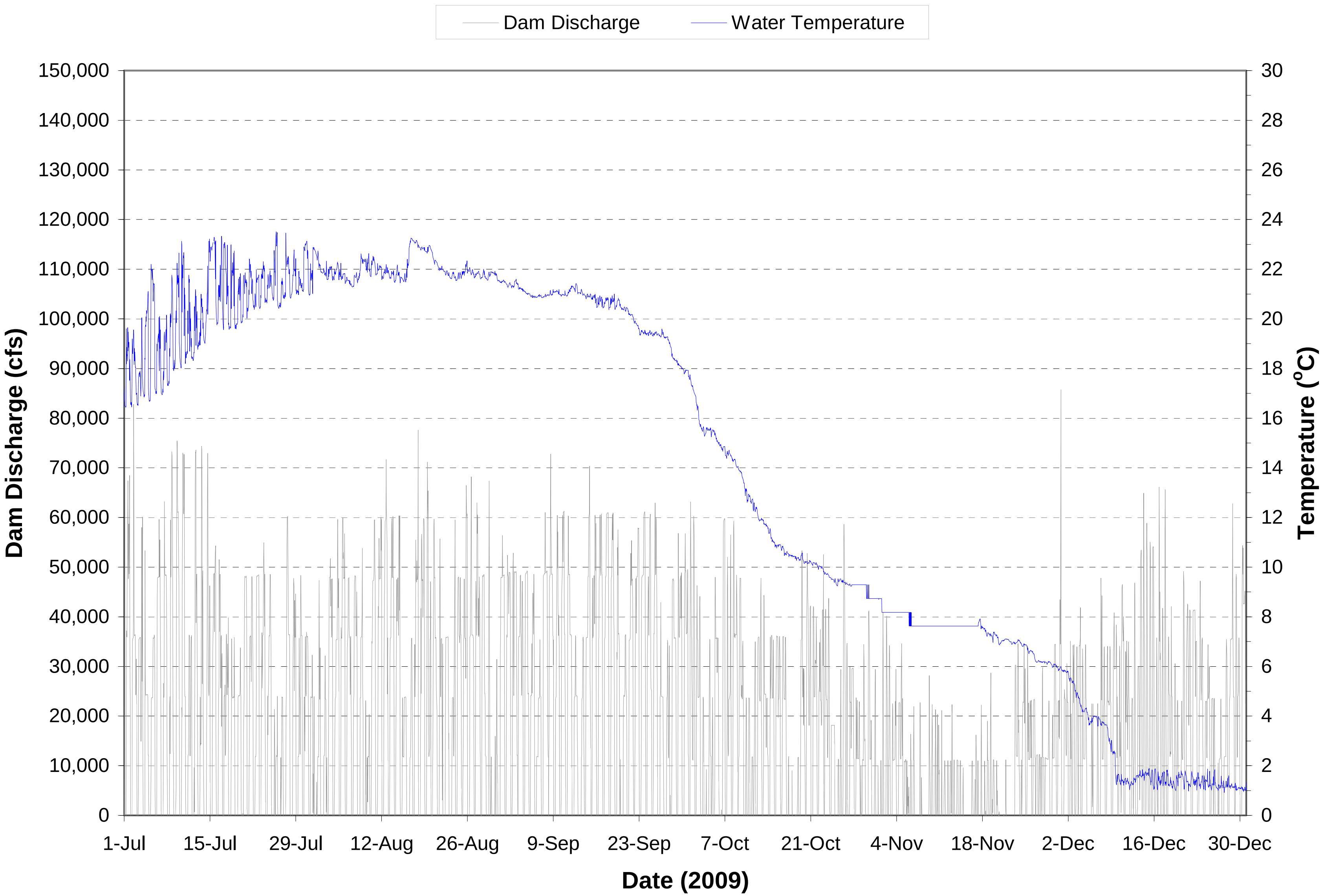


Plate 255. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2009.

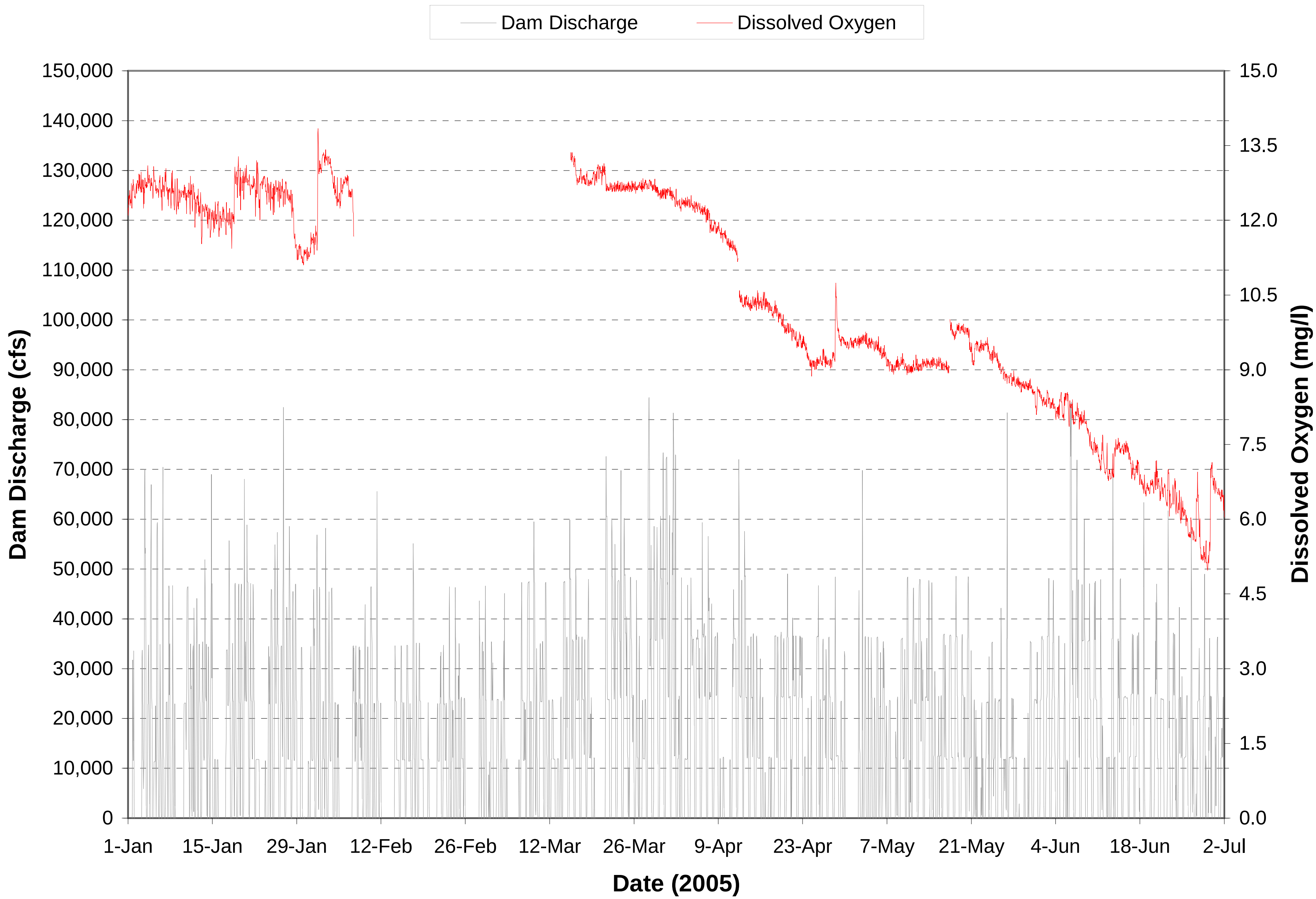


Plate 256. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2005.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

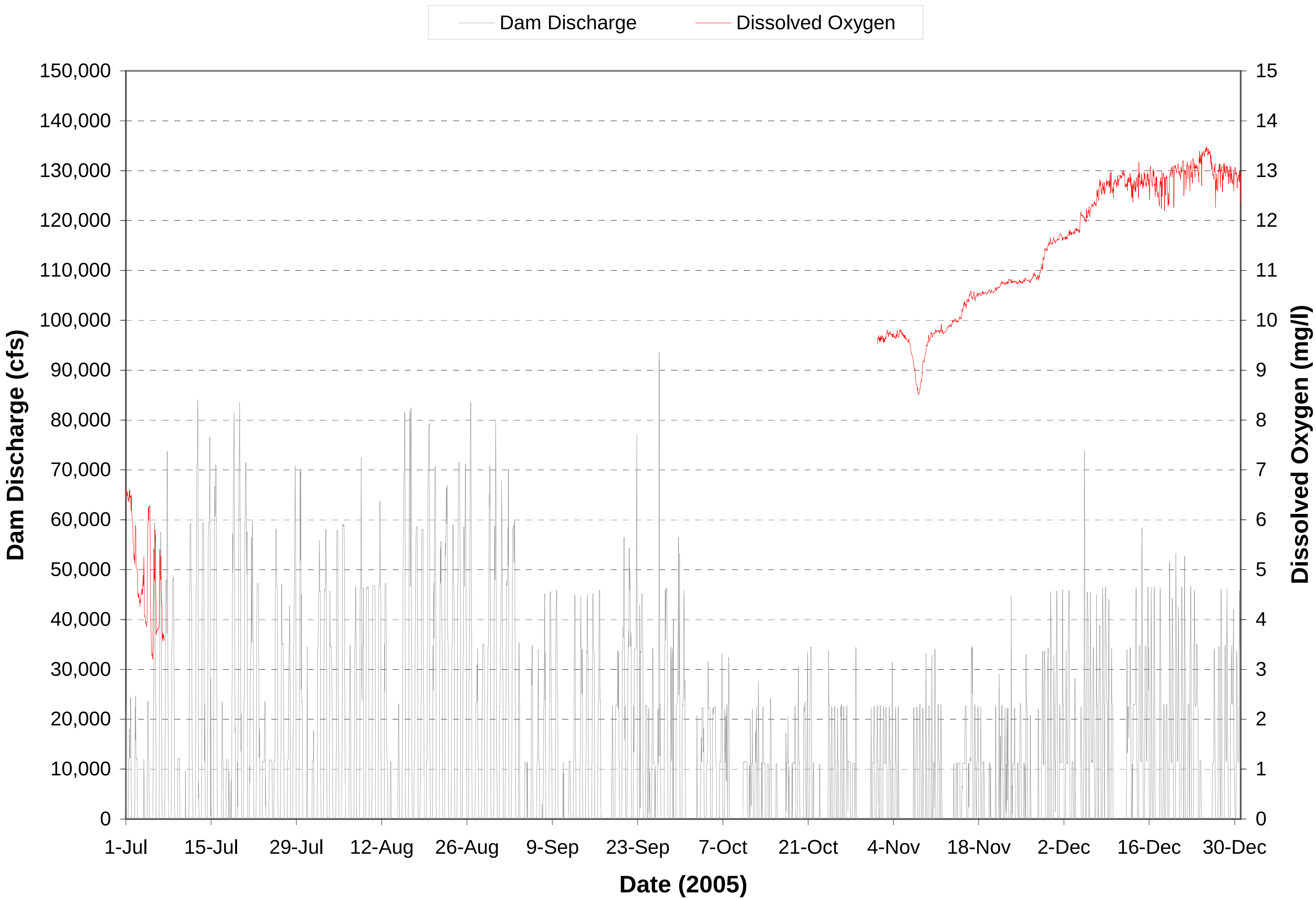


Plate 257. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2005.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

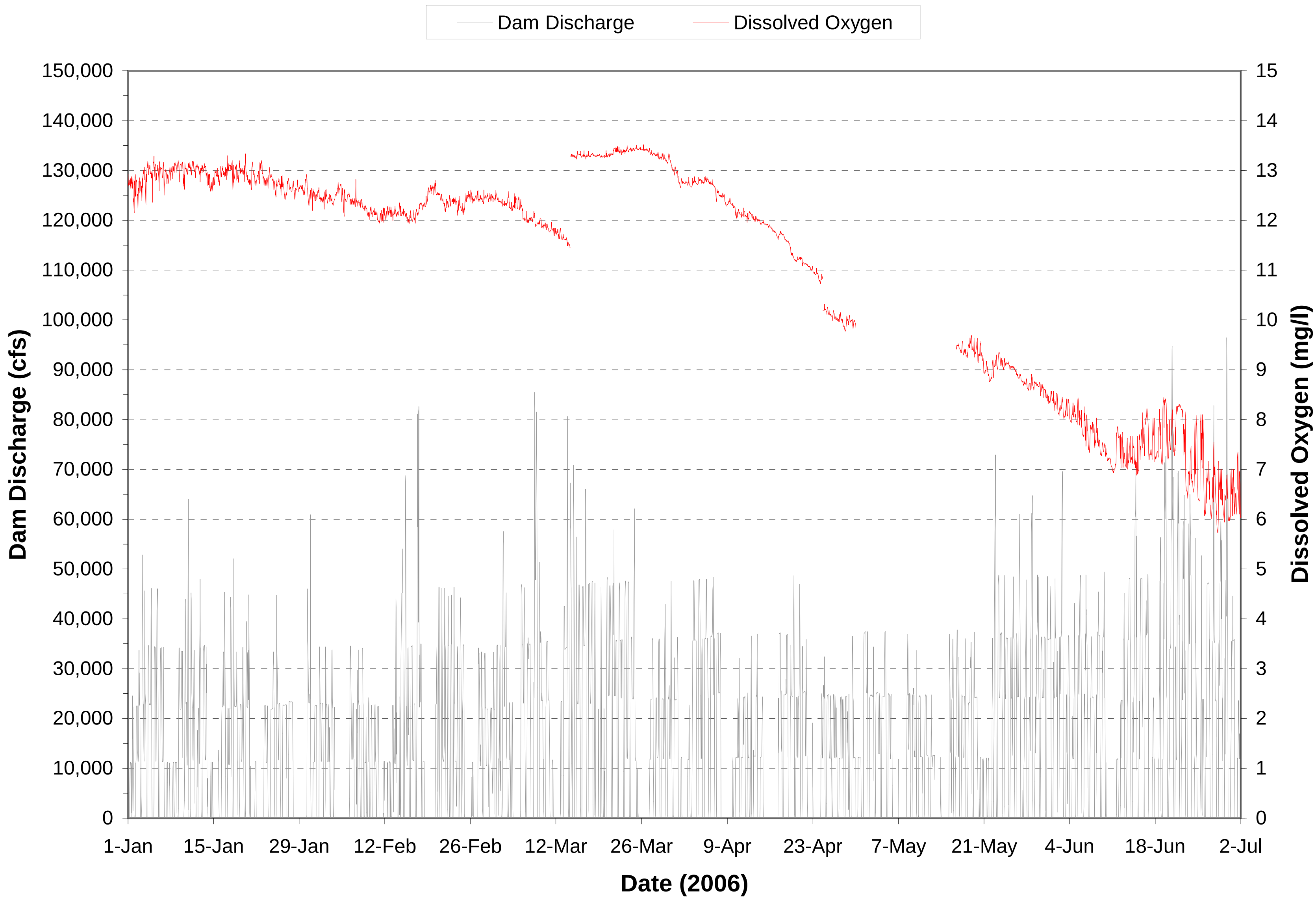


Plate 258. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period January through July 2006.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

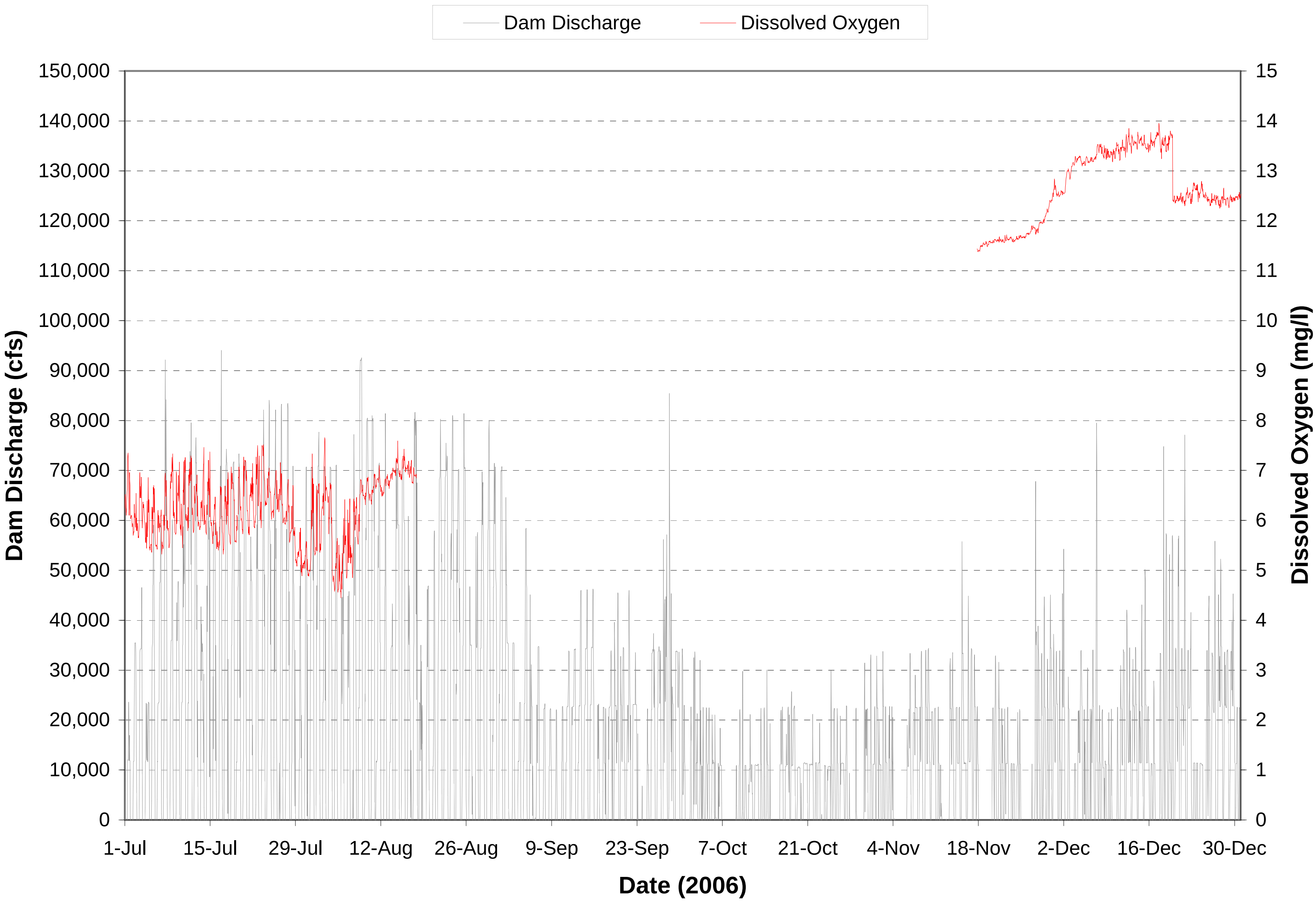


Plate 259. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2006.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

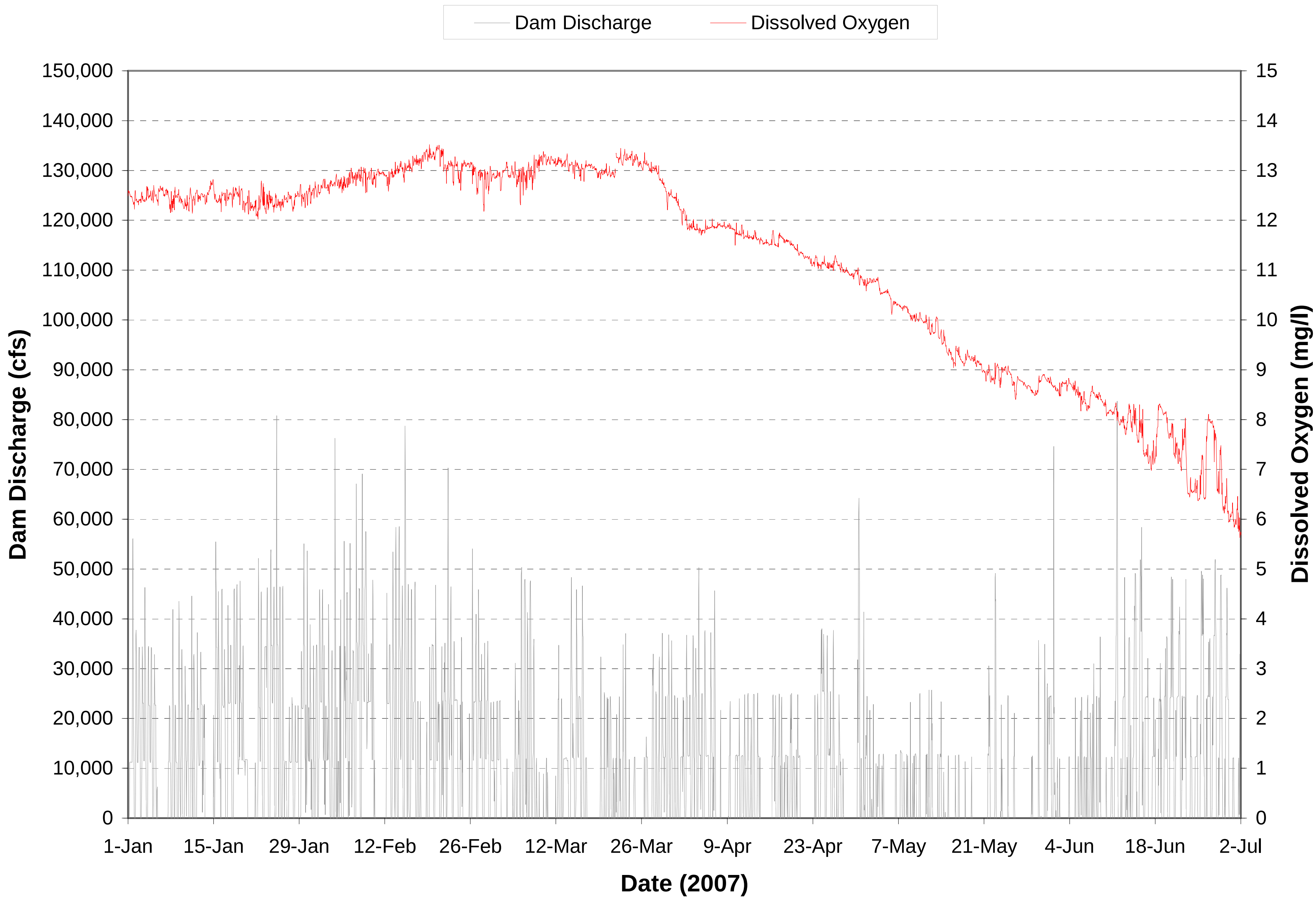


Plate 260. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period January through July 2007.

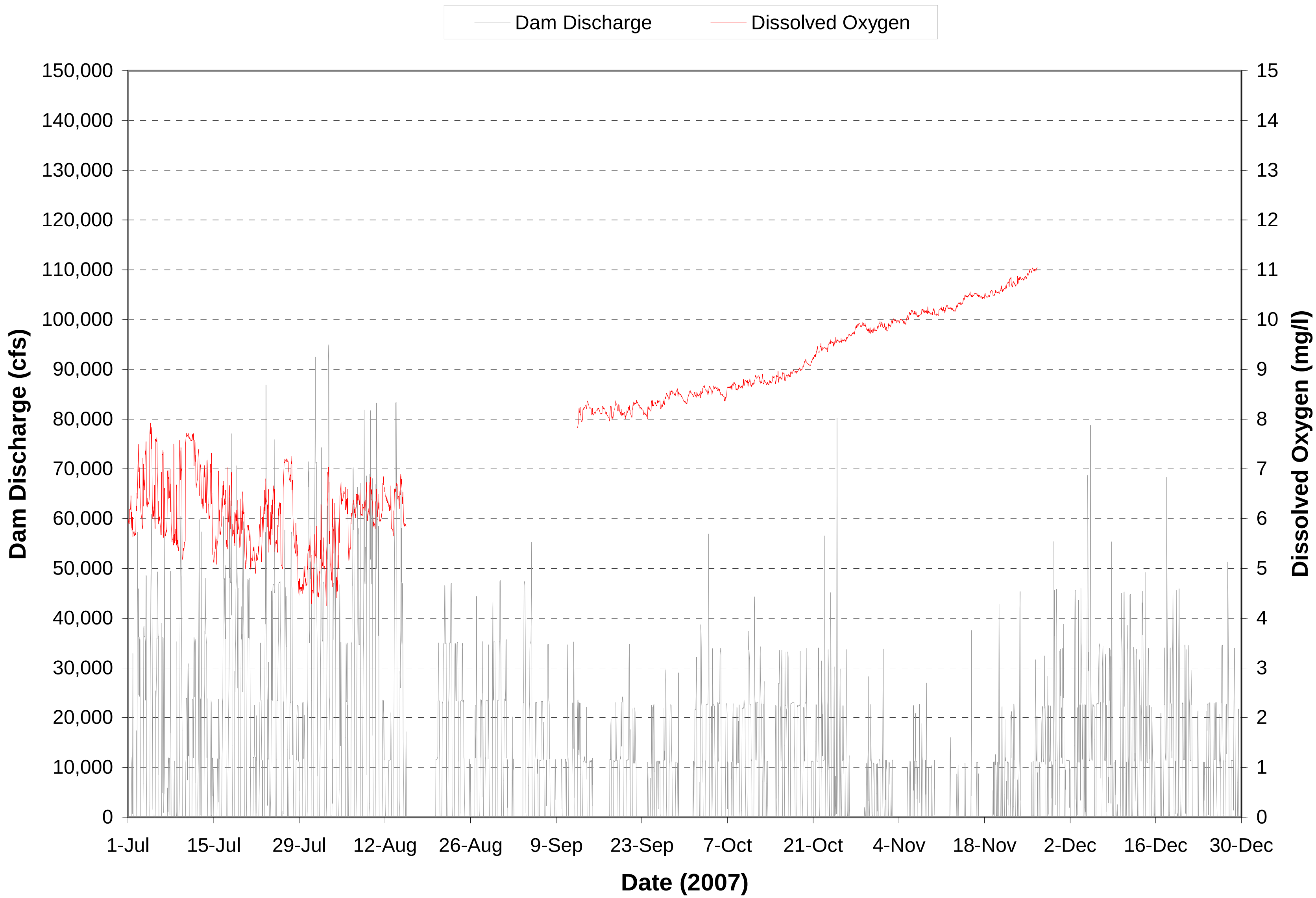


Plate 261. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

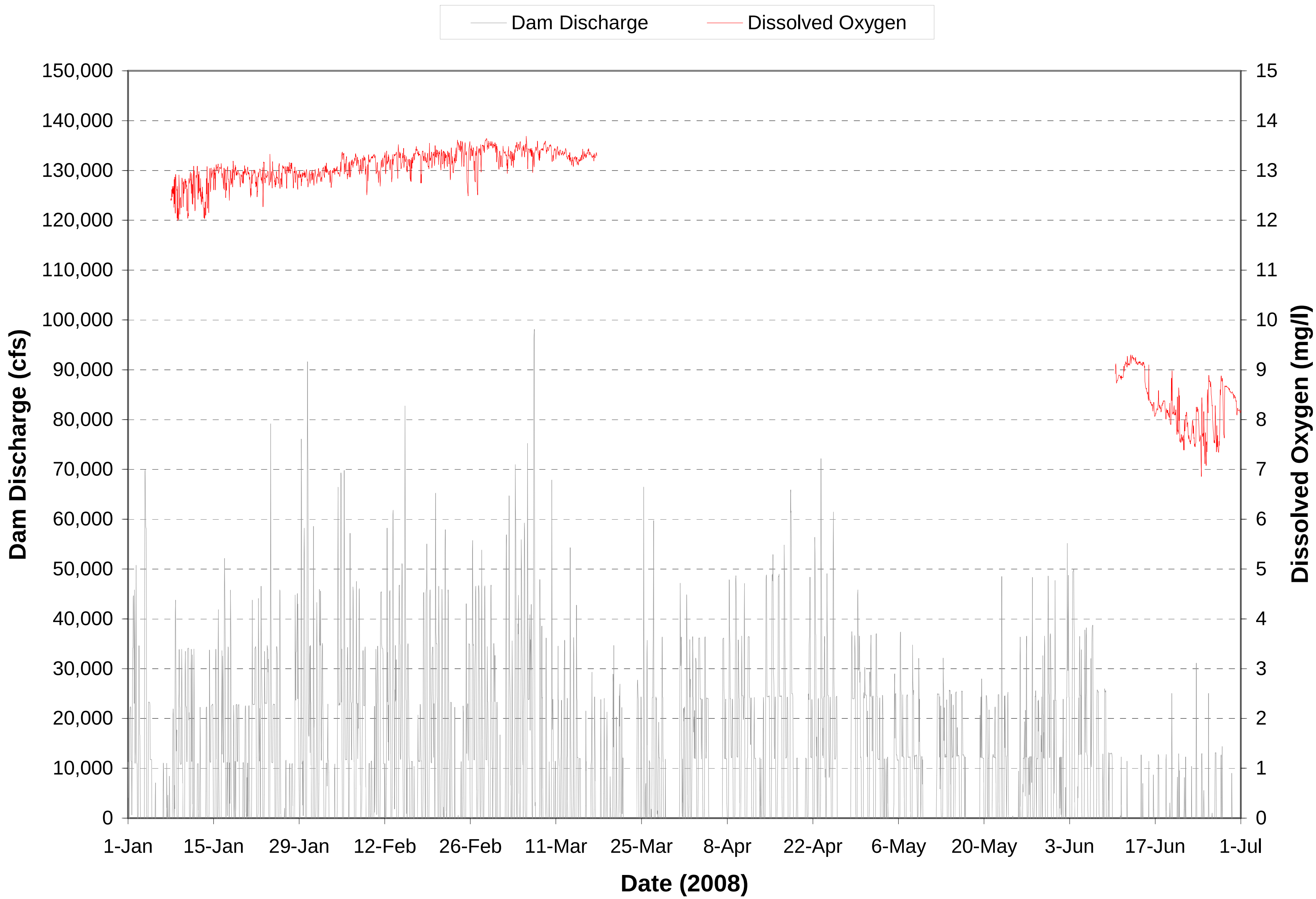


Plate 262. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period January through July 2008.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

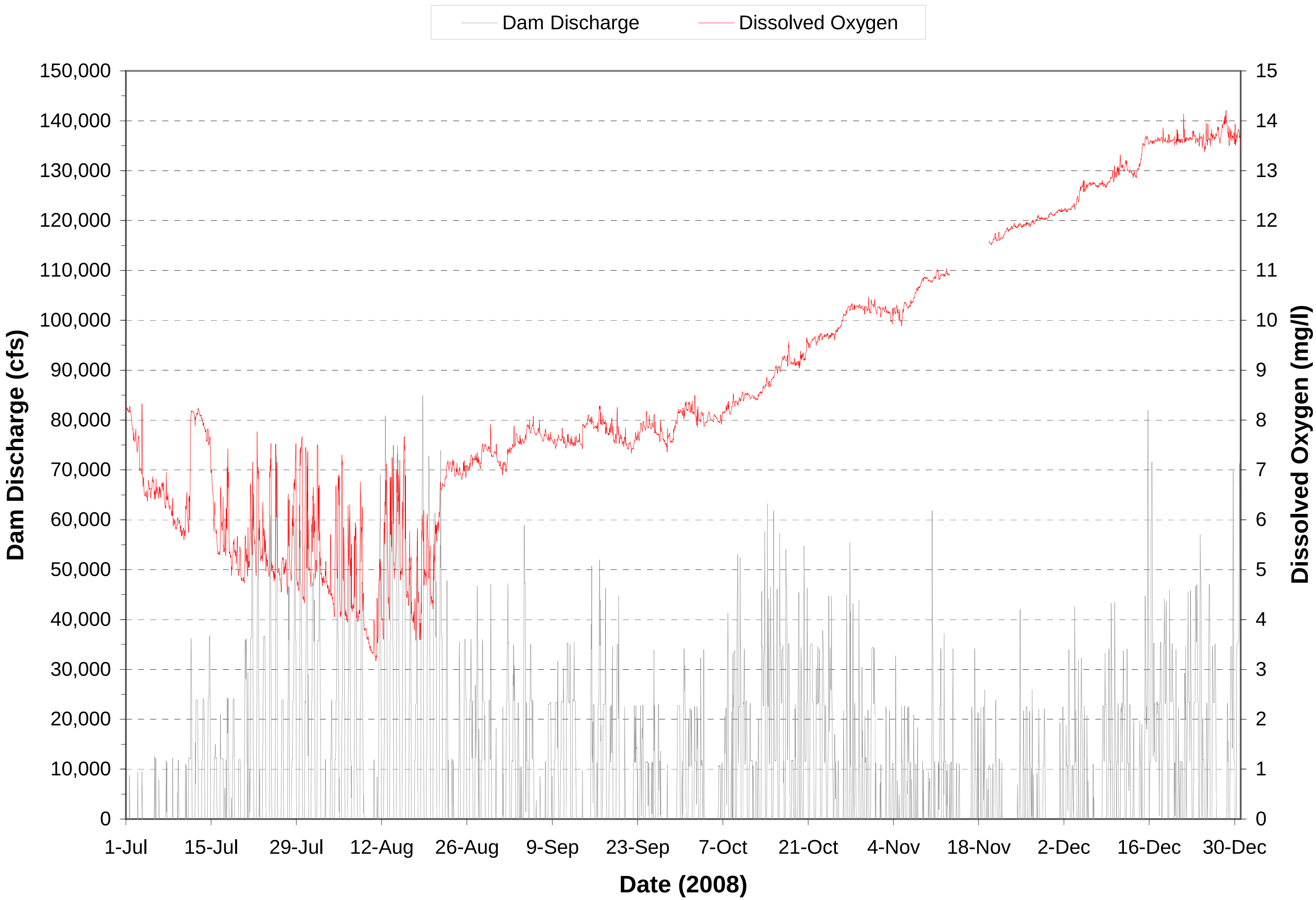


Plate 263. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2008.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

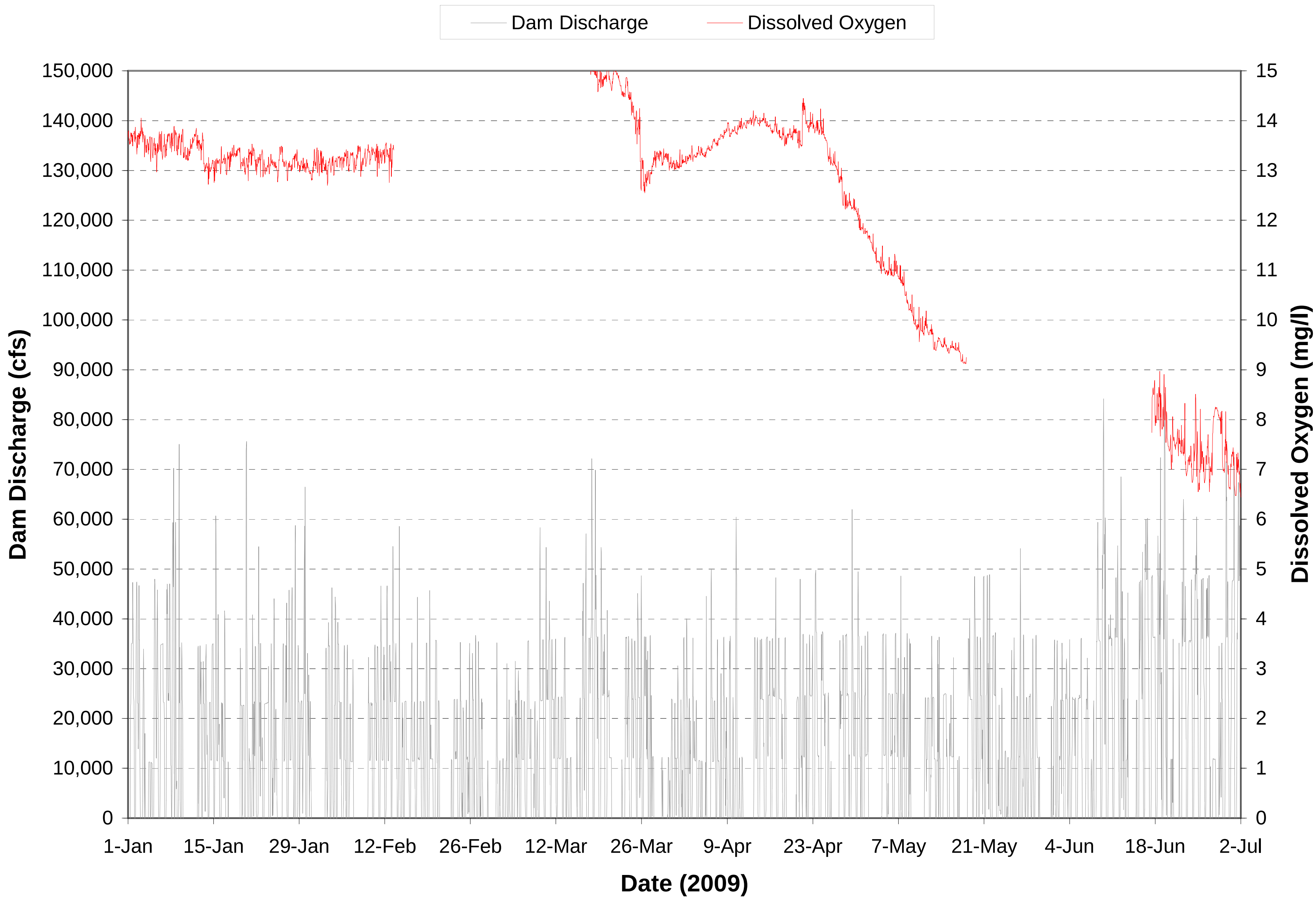


Plate 264. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period January through July 2009.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

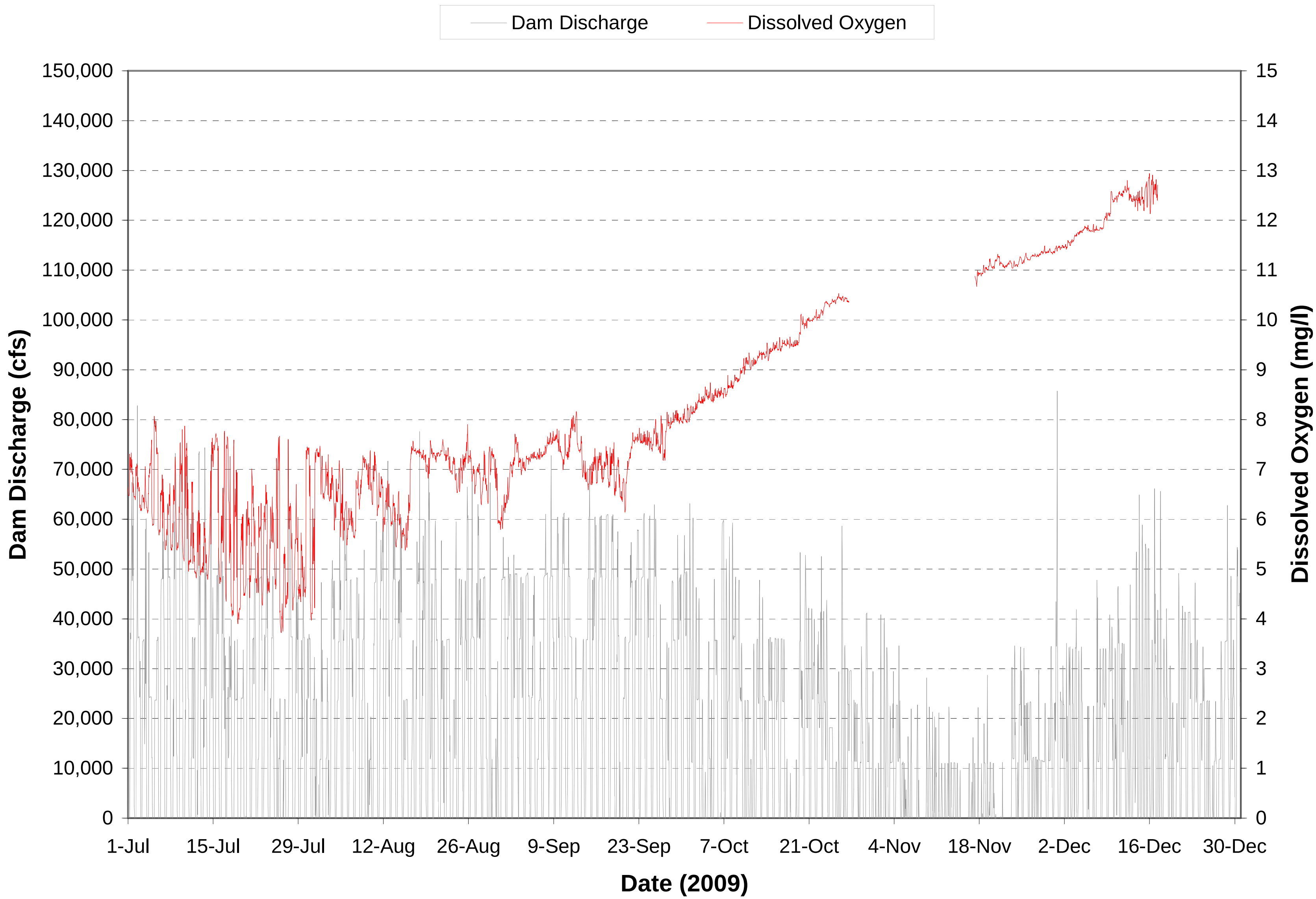


Plate 265. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2009.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

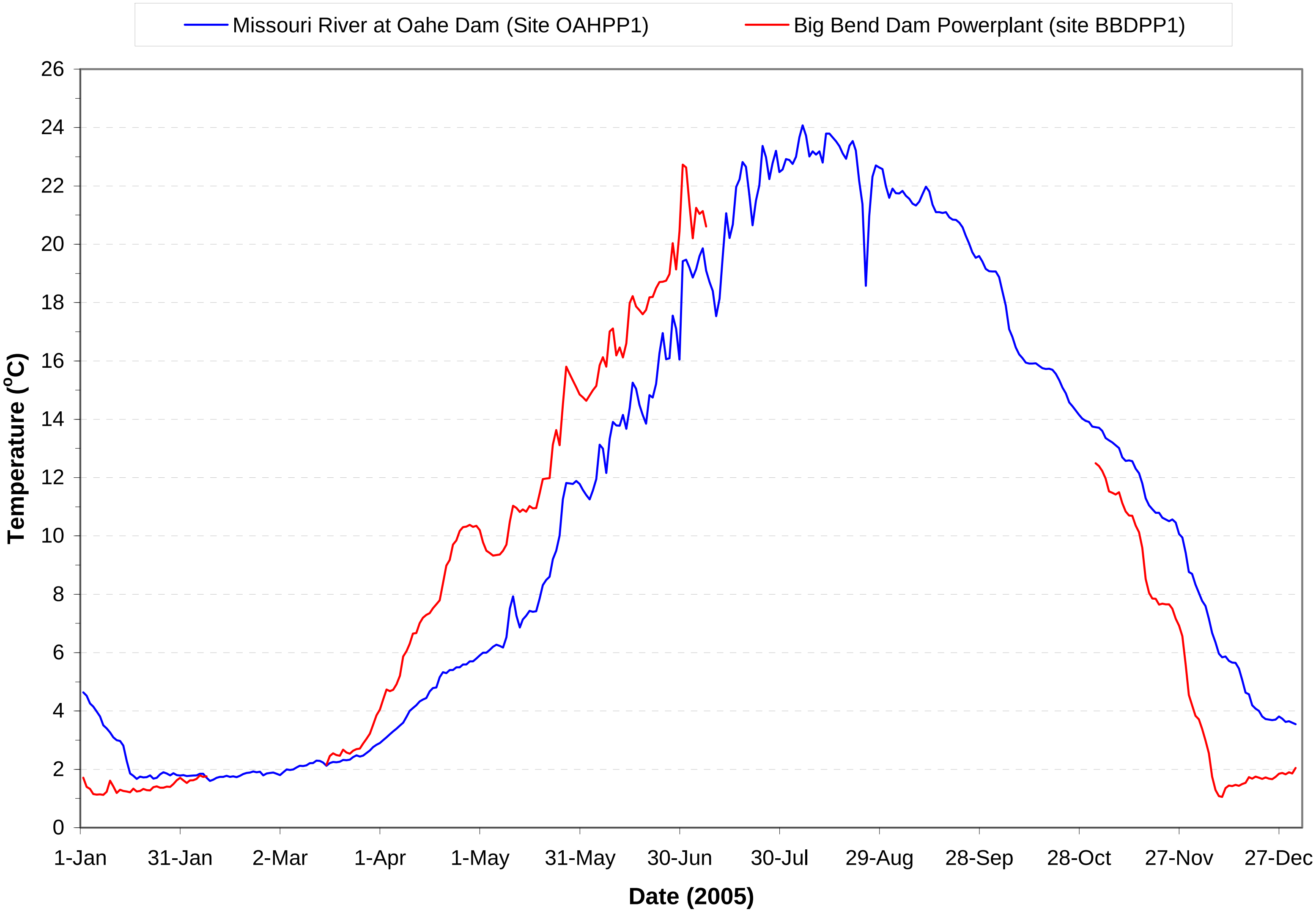


Plate 266. Mean daily water temperatures monitored at the Big Bend Powerplant (i.e., site BBDPP1) and the Missouri River at Oahe Dam (i.e., site OAHPP1) during 2005.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

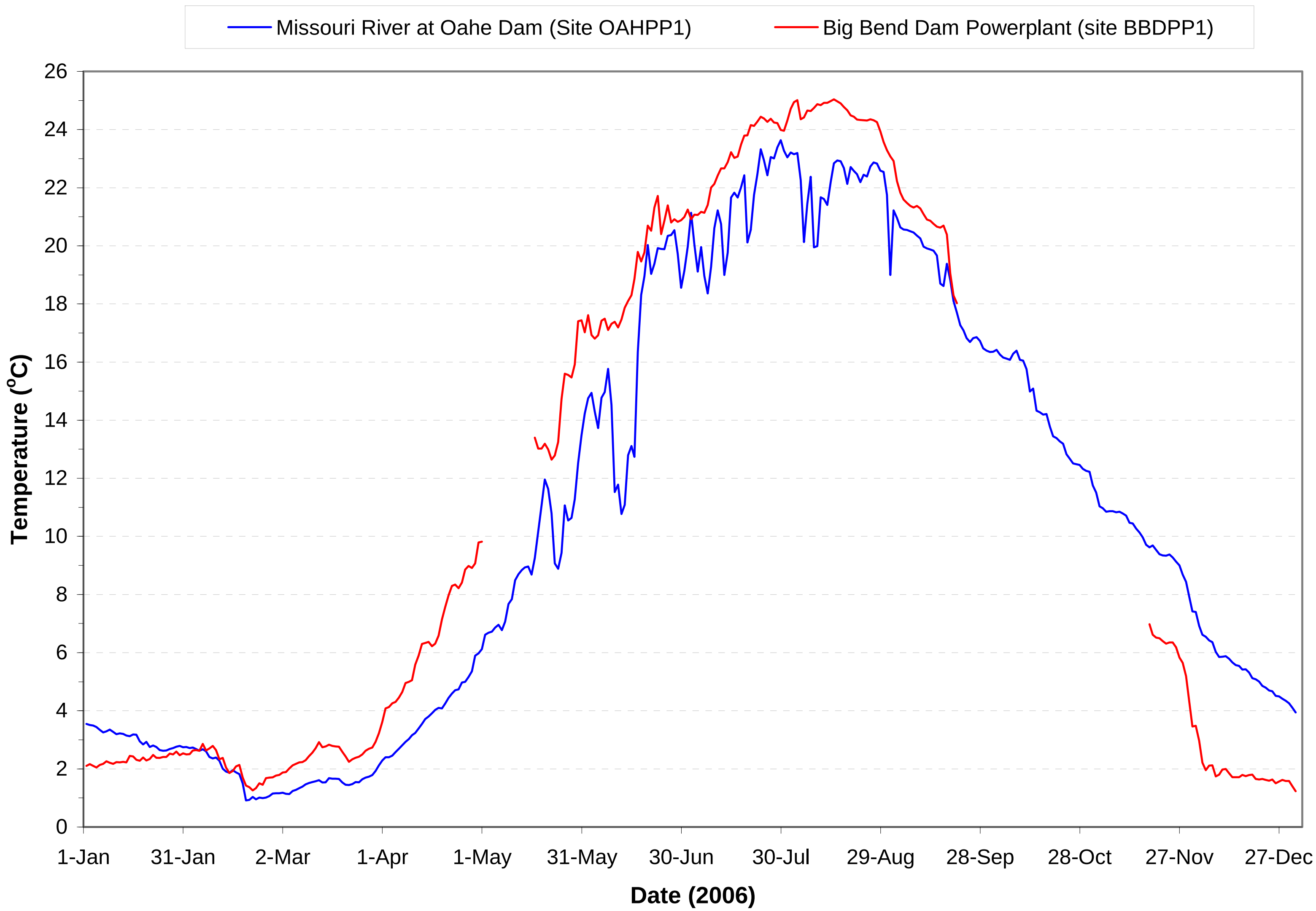


Plate 267. Mean daily water temperatures monitored at the Big Bend Powerplant (i.e., site BBDPP1) and the Missouri River at Oahe Dam (i.e., site OAHPP1) during 2006.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

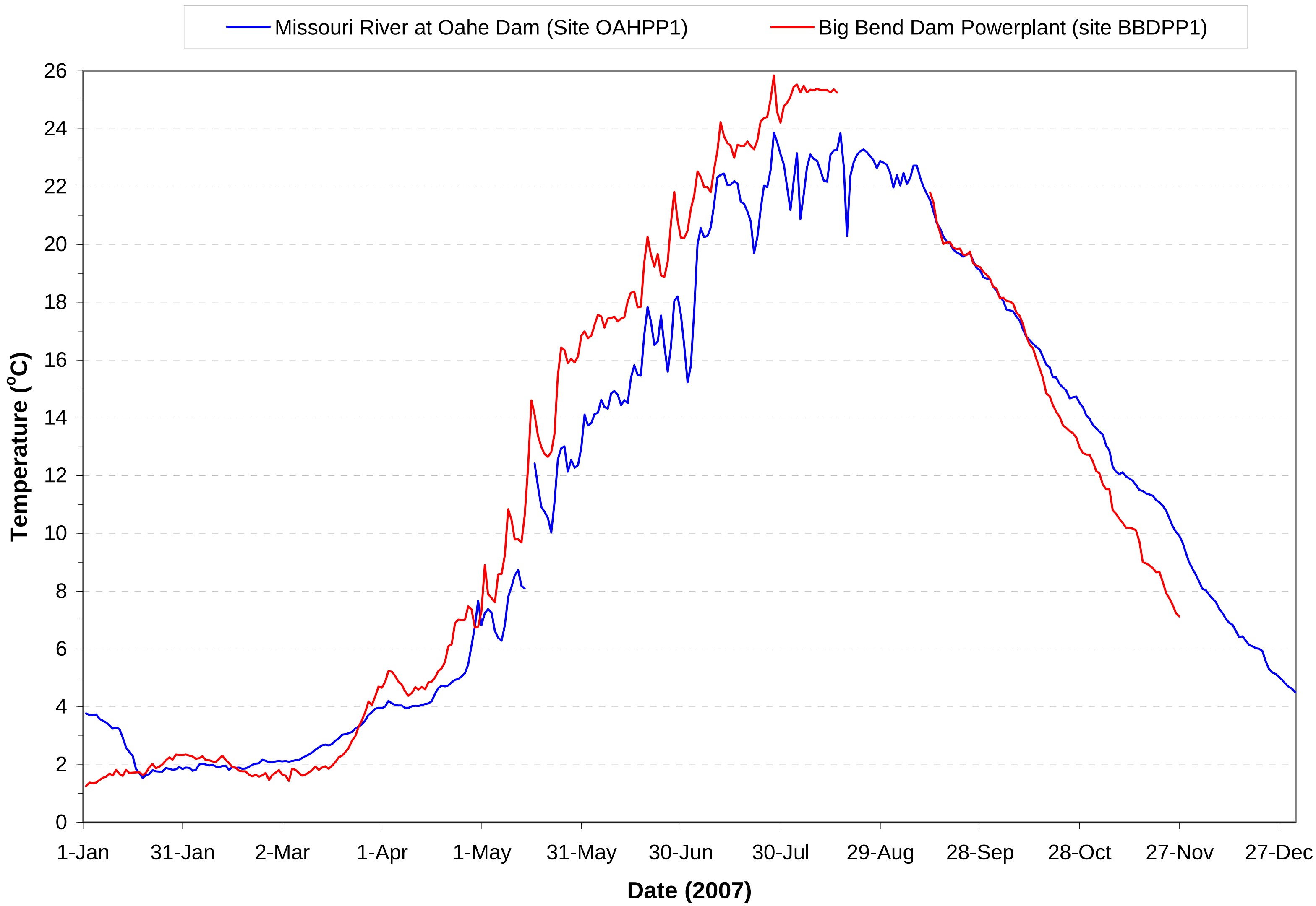


Plate 268. Mean daily water temperatures monitored at the Big Bend Powerplant (i.e., site BBDPP1) and the Missouri River at Oahe Dam (i.e., site OAHPP1) during 2007.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

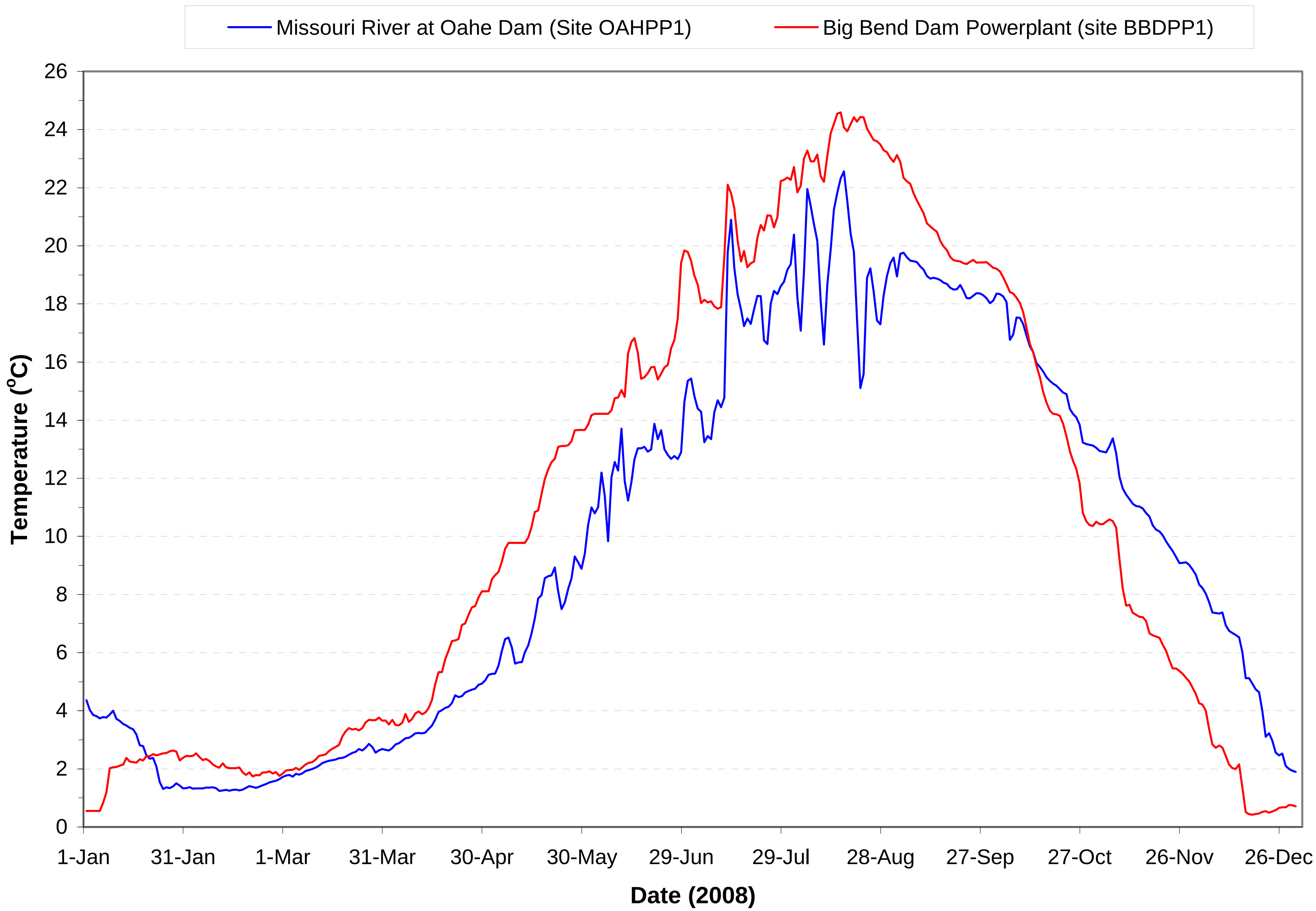


Plate 269. Mean daily water temperatures monitored at the Big Bend Powerplant (i.e., site BBDPP1) and the Missouri River at Oahe Dam (i.e., site OAHPP1) during 2008.

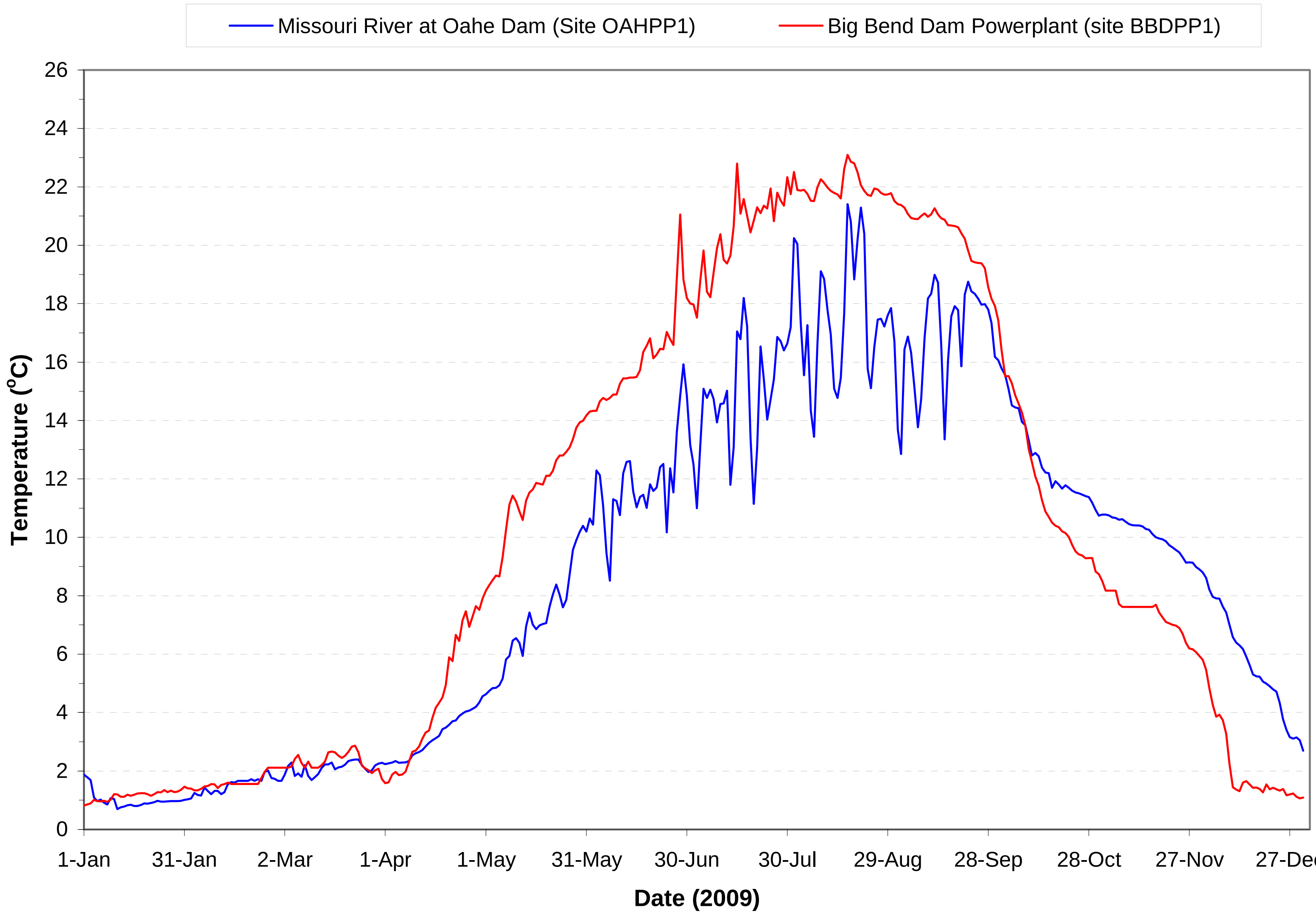


Plate 270. Mean daily water temperatures monitored at the Big Bend Powerplant (i.e., site BBDPP1) and the Missouri River at Oahe Dam (i.e., site OAHPP1) during 2009.

Plate 271. Summary of monthly (May through September) water quality conditions monitored in Lake Francis Case near Fort Randall Dam (Site FTRLK0880A) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results(A)						Water Quality Standards Attainment		
	Detection Limit(B)	No. of Obs.	Mean(C)	Median	Min.	Max.	State WQS Criteria(D)	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	24	1354.6	1355.3	1346.7	1361.8	-----	-----	-----
Water Temperature (°C)	0.1	809	18.6	21.0	6.3	28.1	27(1,5)	3	<1%
Dissolved Oxygen (mg/l)	0.1	806	8.3	8.0	1.8	11.5	5(1,6)	29	4%
Dissolved Oxygen (% Sat.)	0.1	806	91.3	93.9	20.7	107.3	----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)(E)	0.1	724	8.5	8.0	4.8	11.5	5(3,6)	1	<1%
Hypolimnion Dissolved Oxygen (mg/l)(E)	0.1	82	7.0	7.2	1.8	11.2	5(1,6)	28	34%
Specific Conductance (umho/cm)	1	808	715	731	571	789	-----	-----	-----
pH (S.U.)	0.1	776	8.4	8.4	7.4	9.0	6.5(1,2,6), 9.0(1,2,5), 9.5(4,5)	0	0%
Turbidity (NTUs)	1	804	3	2	n.d.	32	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	809	346	337	253	470	-----	-----	-----
Secchi Depth (in.)	1	25	108	101	56	229	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	160	160	140	180	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	46	3.1	3.1	1.6	6.2	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	39	11	11	5	21	-----	-----	-----
Chloride (mg/l)	1	42	11	11	9	14	438(2,5), 250(2,7)	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	424	4	2	n.d.	16	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	24	3	2	n.d.	14	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	44	487	479	440	624	1,750(2,5), 1,000(2,7), 3,500(4,5), 2,000(4,7)	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	48	-----	0.02	n.d.	0.20	2.6 (1,5,8), 0.83 (1,7,8)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	48	0.5	0.4	n.d.	1.2	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	48	-----	n.d.	n.d.	0.24	10(2,5)	0	0%
Nitrogen, Total (mg/l)	0.1	48	0.5	0.4	n.d.	1.2			
Phosphorus, Dissolved (mg/l)	0.02	38	-----	n.d.	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	48	-----	0.03	n.d.	0.25	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	48	-----	n.d.	n.d.	0.06	-----	-----	-----
Sulfate (mg/l)	1	44	212	217	176	230	875(2,5), 500(2,7)	0	0%
Suspended Solids, Total (mg/l)	4	48	-----	n.d.	n.d.	8	158(1,5), 90(1,7)	0	0%
Microcystin, Total (ug/l)	0.2	24	-----	n.d.	n.d.	1.8	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of warmwater permanent fish life propagation waters.
(2) Criteria for the protection of domestic water supply waters.
(3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
(4) Criteria for the protection of commerce and industry waters.
(5) Daily maximum criterion (monitoring results directly comparable to criterion).
(6) Daily minimum criterion (monitoring results directly comparable to criterion).
(7) 30-day average criterion (monitoring results not directly comparable to criterion).
(8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

Plate 272. Summary of monthly (June through September) water quality conditions monitored in Lake Francis Case near Pease Creek (site FTRLK0892DW) during the 3-year period 2006 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	12	1354.0	1354.4	1346.7	1362.0	-----	-----	-----
Water Temperature (°C)	0.1	346	21.2	21.4	9.7	26.2	27[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	345	7.7	7.9	1.5	9.8	5[1,6]	19	6%
Dissolved Oxygen (% Sat.)	0.1	345	89.8	93.3	18.0	104.5	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	301	7.9	7.9	5.2	9.8	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	44	6.2	6.9	1.5	9.8	5[1,6]	19	43%
Specific Conductance (umho/cm)	1	346	728	730	698	740	-----	-----	-----
pH (S.U.)	0.1	317	8.4	8.4	7.7	8.8	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	345	3	2	n.d.	23	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	346	329	320	252	427	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	341	2	1	n.d.	5	-----	-----	-----
Secchi Depth (in)	1	11	107	96	56	194	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. The mean is not reported if 20% or more of the observations were nondetects. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment

Plate 273. **S**ummary of monthly (June through September) water quality conditions monitored in Lake Francis Case near Platte Creek (Site FTRLK0911DW) during the 4-year period 2006 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	16	1354.5	1355.0	1346.7	1361.9	-----	-----	-----
Water Temperature (°C)	0.1	390	20.7	21.9	9.1	26.5	27(1,5)	0	0%
Dissolved Oxygen (mg/l)	0.1	390	7.9	7.9	0.9	9.7	5(1,6)	12	3%
Dissolved Oxygen (% Sat.)	0.1	390	90.8	93.4	10.4	116.8	----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	350	8.0	8.0	5.2	10.4	5(3,6)	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	40	6.3	6.6	0.9	9.7	5(1,6)	12	30%
Specific Conductance (umho/cm)	1	390	731	730	703	779	-----	-----	-----
pH (S.U.)	0.1	366	8.4	8.5	7.7	8.8	6.5(1,2,6), 9.0(1,2,5), 9.5(4,5)	0	0%
Turbidity (NTUs)	1	390	4	3	n.d.	26	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	390	327	319	247	425	-----	-----	-----
Secchi Depth (in.)	1	16	83	77	48	148	-----	-----	-----
Alkalinity, Total (mg/l)	7	31	159	155	110	319	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	29	3.1	3.0	2.2	3.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	30	12	13	4	19	-----	-----	-----
Chloride (mg/l)	1	31	12	12	9	14	438(2,5), 250(2,7)	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	283	6	5	n.d.	20	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	16	6	5	1	16	-----	-----	-----
Dissolved Solids, Total (mg/l)	4	31	489	482	448	592	1,750(2,5), 1,000(2,7), 3,500(4,5), 2,000(4,7)	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	31	-----	0.02	n.d.	0.23	3.9 (1,5,8), 0.76 (1,7,8)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	31	0.5	0.5	n.d.	1.2	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	31	-----	n.d.	n.d.	0.19	10(2,5)	0	0%
Nitrogen, Total (mg/l)	0.1	31	0.5	0.5	n.d.	1.2	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	31	-----	n.d.	n.d.	0.05	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	31	-----	0.03	n.d.	0.11	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	31	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	31	211	216	180	270	875(2,5), 500(2,7)	0	0%
Suspended Solids, Total (mg/l)	4	31	-----	n.d.	n.d.	15	158(1,5), 90(1,7)	0	0%
Microcystin, Total (ug/l)	0.2	16	-----	n.d.	n.d.	0.3	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

Plate 274. Summary of monthly (June through September) water quality conditions monitored in Lake Francis Case near Snake Creek (site FTRLK0924DW) during the 3-year period 2006 through 2008

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	12	1354.0	1354.4	1347.1	1362.0	-----	-----	-----
Water Temperature (°C)	0.1	214	22.2	22.9	11.6	27.2	27[(1,5)]	1	<1%
Dissolved Oxygen (mg/l)	0.1	214	7.9	7.9	3.2	9.5	5[(1,6)]	19	6%
Dissolved Oxygen (% Sat.)	0.1	214	93.7	94.7	39.4	114.4	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	199	7.9	7.9	6.2	9.5	5[(3,6)]	1	<1%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	15	7.2	6.7	3.2	9.2	5[(1,6)]	1	7%
Specific Conductance (umho/cm)	1	214	721	720	693	738	-----	-----	-----
pH (S.U.)	0.1	196	8.4	8.5	7.8	8.6	6.5[(1,2,6)], 9.0[(1,2,5)], 9.5[(4,5)]	0	0%
Turbidity (NTUs)	1	213	9	8	2	58	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	214	330	314	255	498	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	211	3	2	n.d.	21	-----	-----	-----
Secchi Depth (in)	1	12	47	47	25	84	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. The mean is not reported if 20% or more of the observations were nondetects. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment

Plate 275. **S**ummary of monthly (June through September) water quality conditions monitored in Lake Francis Case near Elm Creek (Site FTRLK0940DW) during the 4-year period 2006 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	15	1355.1	1355.2	1347.1	1361.9	-----	-----	-----
Water Temperature (°C)	0.1	84	21.9	22.6	13.8	26.4	27[(1,5)]	0	0%
Dissolved Oxygen (mg/l)	0.1	84	8.6	8.6	7.6	9.9	5[(1,6)]	0	0%
Dissolved Oxygen (% Sat.)	0.1	84	102.1	101.4	92.1	115.1	----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	84	8.6	8.6	7.6	9.9	5[(3,6)]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0[F]	-----	-----	-----	-----	5[(1,6)]	-----	-----
Specific Conductance (umho/cm)	1	84	730	730	701	793	-----	-----	-----
pH (S.U.)	0.1	78	8.4	8.4	8.1	8.7	6.5[(1,2,6)], 9.0[(1,2,5)], 9.5[(4,5)]	0	0%
Turbidity (NTUs)	1	84	22	13	n.d.	284	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	84	330	325	265	408	-----	-----	-----
Secchi Depth (in.)	1	14	29	26	7	52	-----	-----	-----
Alkalinity, Total (mg/l)	7	29	154	157	131	170	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	27	3.1	3.2	1.7	4.0	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	29	13	13	n.d.	30	-----	-----	-----
Chloride (mg/l)	1	29	11	12	9	14	438[(2,5)], 250[(2,7)]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	63	14	8	3	56	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	15	8	8	n.d.	19	-----	-----	-----
Dissolved Solids, Total (mg/l)	4	29	491	480	444	698	1,750[(2,5)], 1,000[(2,7)], 3,500[(4,5)], 2,000[(4,7)]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	29	-----	n.d.	n.d.	0.24	3.9 [(1,5,8)], 0.73 [(1,7,8)]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	29	0.5	0.5	n.d.	1.2	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	29	-----	n.d.	n.d.	0.30	10[(2,5)]	0	0%
Nitrogen, Total (mg/l)	0.1	29	0.6	0.6	n.d.	1.2	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	29	-----	n.d.	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	29	0.04	0.04	n.d.	0.13	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	29	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	29	208	210	176	241	875[(2,5)], 500[(2,7)]	0	0%
Suspended Solids, Total (mg/l)	4	29	18	7	n.d.	140	158[(1,5)], 90[(1,7)]	0, 2	0%, 7%
Microcystin, Total (ug/l)	0.2	15	-----	n.d.	n.d.	0.2	-----	-----	-----

n.d. = Not detected.

[A] Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

[B] Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

[C] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[D] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

[E] A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

[F] Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

Plate 276. Summary of monthly (June through September) water quality conditions monitored in Lake Francis Case near the White River (site FTRLK0955DW) during the 3-year period 2006 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	12	1354.0	1354.3	1347.1	1361.6	-----	-----	-----
Water Temperature (°C)	0.1	50	22.6	24.4	14.9	26.0	27[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	49	8.1	8.1	0.1	9.5	5[1,6]	19	6%
Dissolved Oxygen (% Sat.)	0.1	49	96.9	100.8	1.6	104.1	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	49	8.1	8.1	0.1	9.5	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0[F]	-----	-----	-----	-----	5[1,6]	-----	-----
Specific Conductance (umho/cm)	1	50	706	704	559	735	-----	-----	-----
pH (S.U.)	0.1	45	8.4	8.5	8.0	8.7	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	47	33	20	8	210	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	50	354	311	250	614	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	49	5	4	n.d.	12	-----	-----	-----
Secchi Depth (in)	1	11	20	18	11	32	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. The mean is not reported if 20% or more of the observations were nondetects. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

Plate 277. **S**ummary of monthly (June through September) water quality conditions monitored in Lake Francis Case near Chamberlain, SD (Site FTRLK0968DW) during the 4-year period 2006 through 2009.

	Monitoring Results[(A)]						Water Quality Standards Attainment		
Parameter	**Detection Limit[(B)]**	**No. of Obs.**	**Mean[(C)]**	**Median**	**Min.**	**Max.**	**State WQS Criteria[(D)]**	**No. of WQS Exceedances**	**Percent WQS Exceedance**
Pool Elevation (ft-msl)	0.1	17	1354.5	1355.1	1347.1	1361.6	-----	-----	-----
Water Temperature (°C)	0.1	109	21.3	21.9	13.2	28.3	27[(1,5)]	1	1%
Dissolved Oxygen (mg/l)	0.1	109	8.6	8.5	7.6	10.0	5[(1,6)]	0	0%
Dissolved Oxygen (% Sat.)	0.1	109	99.7	99.6	92.4	112.1	----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[(E)]	0.1	109	8.6	8.5	7.6	10.0	5[(1,6)]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[(E)]	0.1	0[(F)]	-----	-----	-----	-----	5[(1,6)]	-----	-----
Specific Conductance (umho/cm)	1	109	725	729	673	789	-----	-----	-----
pH (S.U.)	0.1	103	8.4	8.4	8.1	8.7	6.5[(1,2,6)], 9.0[(1,2,5)], 9.5[(4,5)]	0	0%
Turbidity (NTUs)	1	109	16	14	6	40	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	109	345	315	258	545	-----	-----	-----
Secchi Depth (in.)	1	16	23	24	14	34	-----	-----	-----
Alkalinity, Total (mg/l)	7	29	157	160	140	170	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	27	2.9	2.8	1.5	5.3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	29	11	11	n.d.	20	-----	-----	-----
Chloride (mg/l)	1	29	11	11	9	14	438[(2,5)], 250[(2,7)]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	82	14	10	3	51	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	17	9	7	n.d.	34	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	29	500	490	450	582	1,750[(2,5)], 1,000[(2,7)], 3,500[(4,5)], 2,000[(4,7)]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	29	-----	0.02	n.d.	01.22	3.9 [(1,5,8)], 0.76 [(1,7,8)]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	29	0.6	0.5	n.d.	2.5	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	29	-----	n.d.	n.d.	0.11	10[(2,5)]	0	0%
Nitrogen, Total (mg/l)	0.1	29	0.6	0.5	0.1	2.5	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	29	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	29	0.06	0.04	n.d.	0.31	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	29	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	29	204	205	173	238	875[(2,5)], 500[(2,7)]	0	0%
Suspended Solids, Total (mg/l)	4	29	12	12	n.d.	27	158[(1,5)], 90[(1,7)]	0	0%
Microcystin, Total (ug/l)	0.2	17	-----	n.d.	n.d.	0.3	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

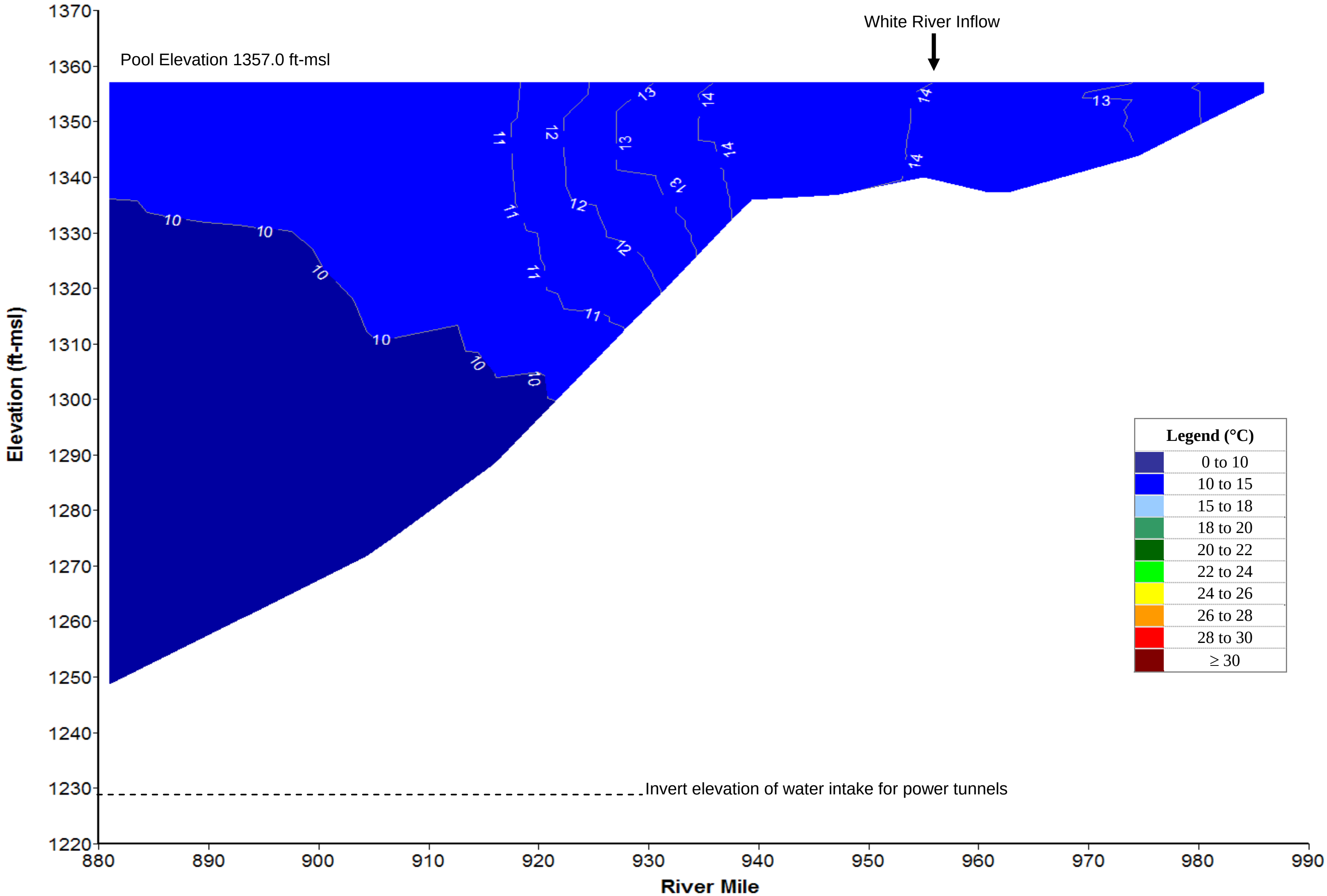


Plate 278. Longitudinal water temperature (°C) contour plot of Lake Francis Case based on depth-profile water temperatures measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on May 12, 2009.

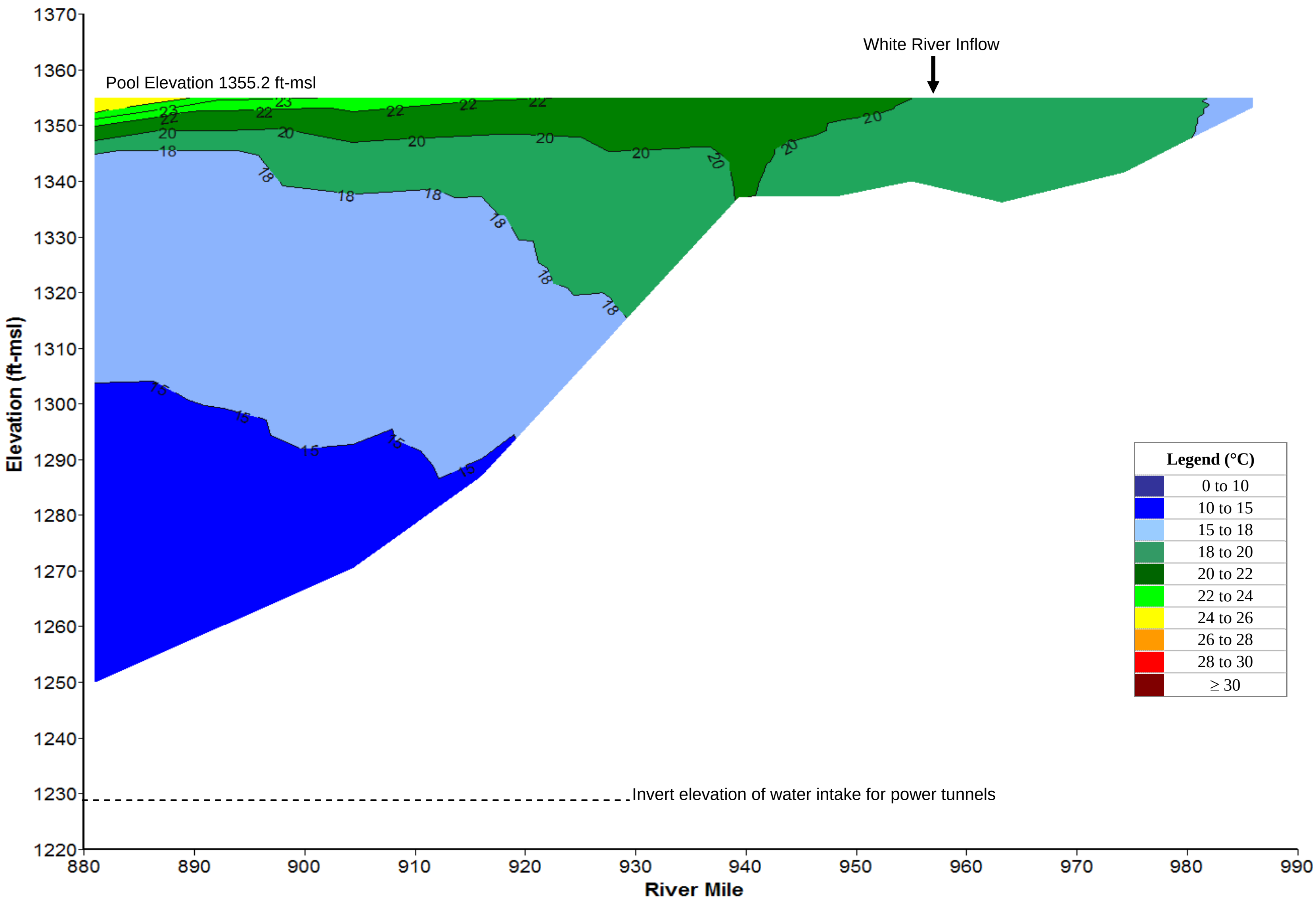


Plate 279. Longitudinal water temperature (°C) contour plot of Lake Francis Case based on depth-profile water temperatures measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on June 17, 2009.

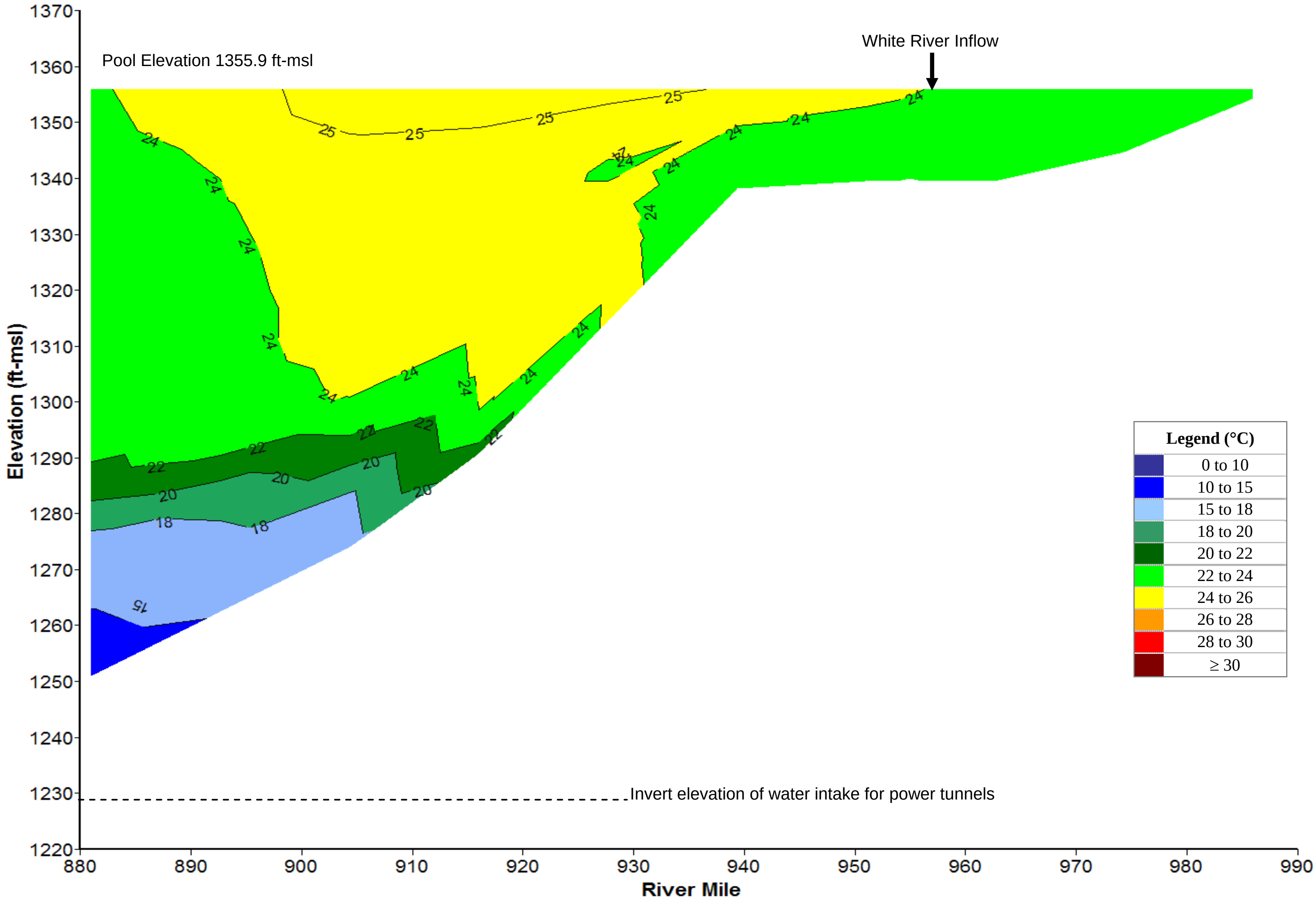


Plate 280. Longitudinal water temperature (°C) contour plot of Lake Francis Case based on depth-profile water temperatures measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on July 15, 2009.

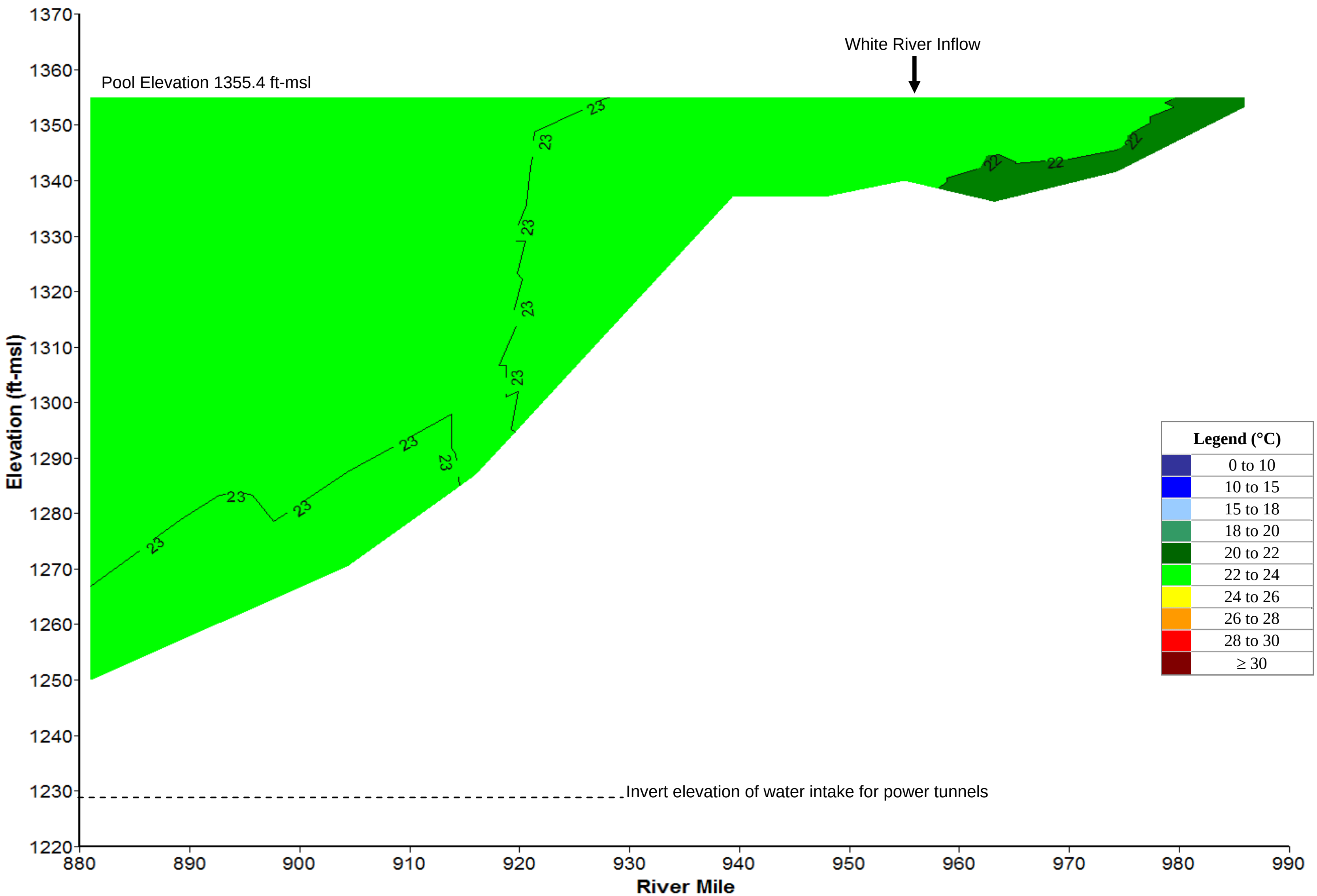


Plate 281. Longitudinal water temperature (°C) contour plot of Lake Francis Case based on depth-profile water temperatures measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on August 25, 2009.

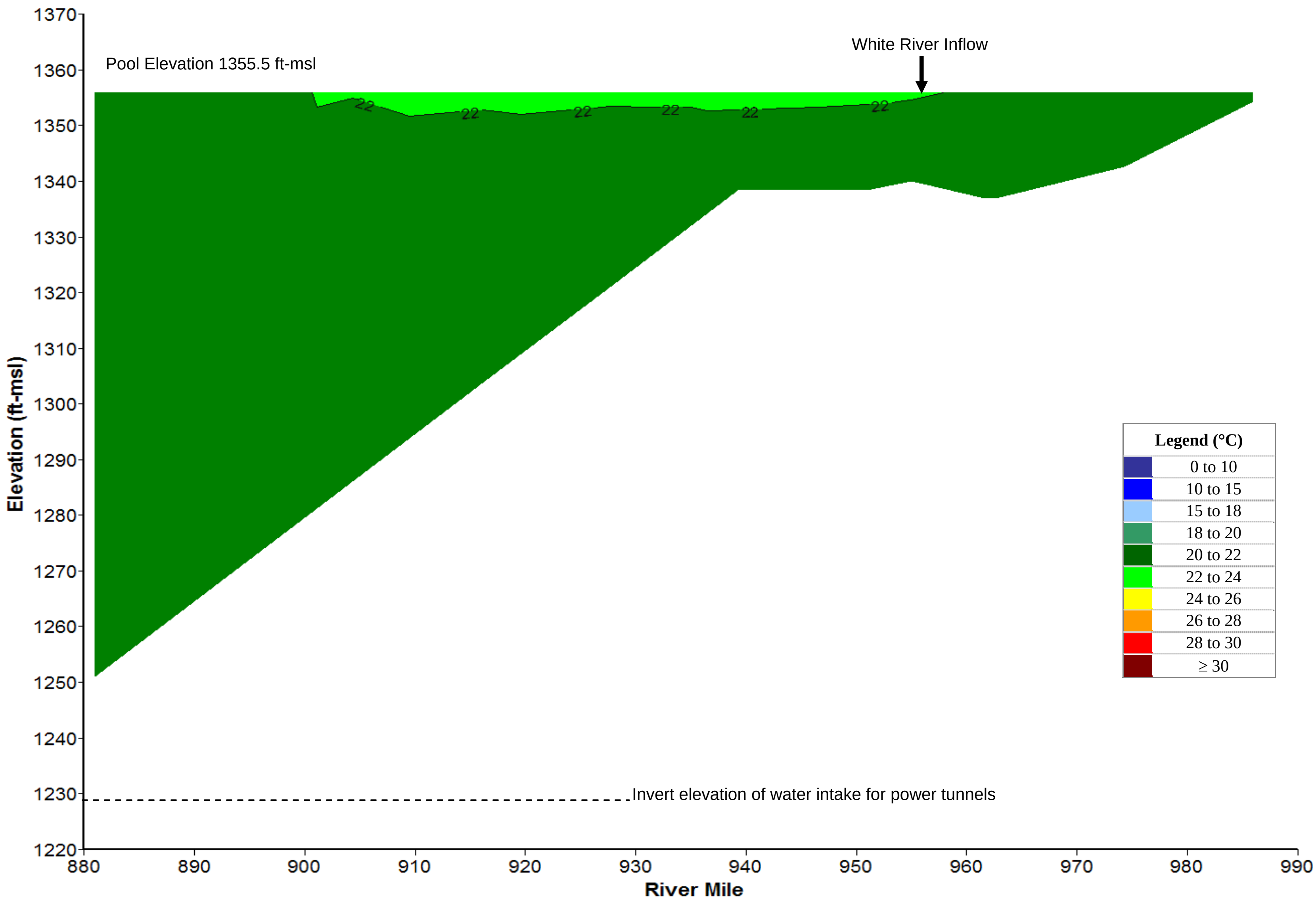


Plate 282. Longitudinal water temperature (°C) contour plot of Lake Francis Case based on depth-profile water temperatures measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on September 17, 2009.

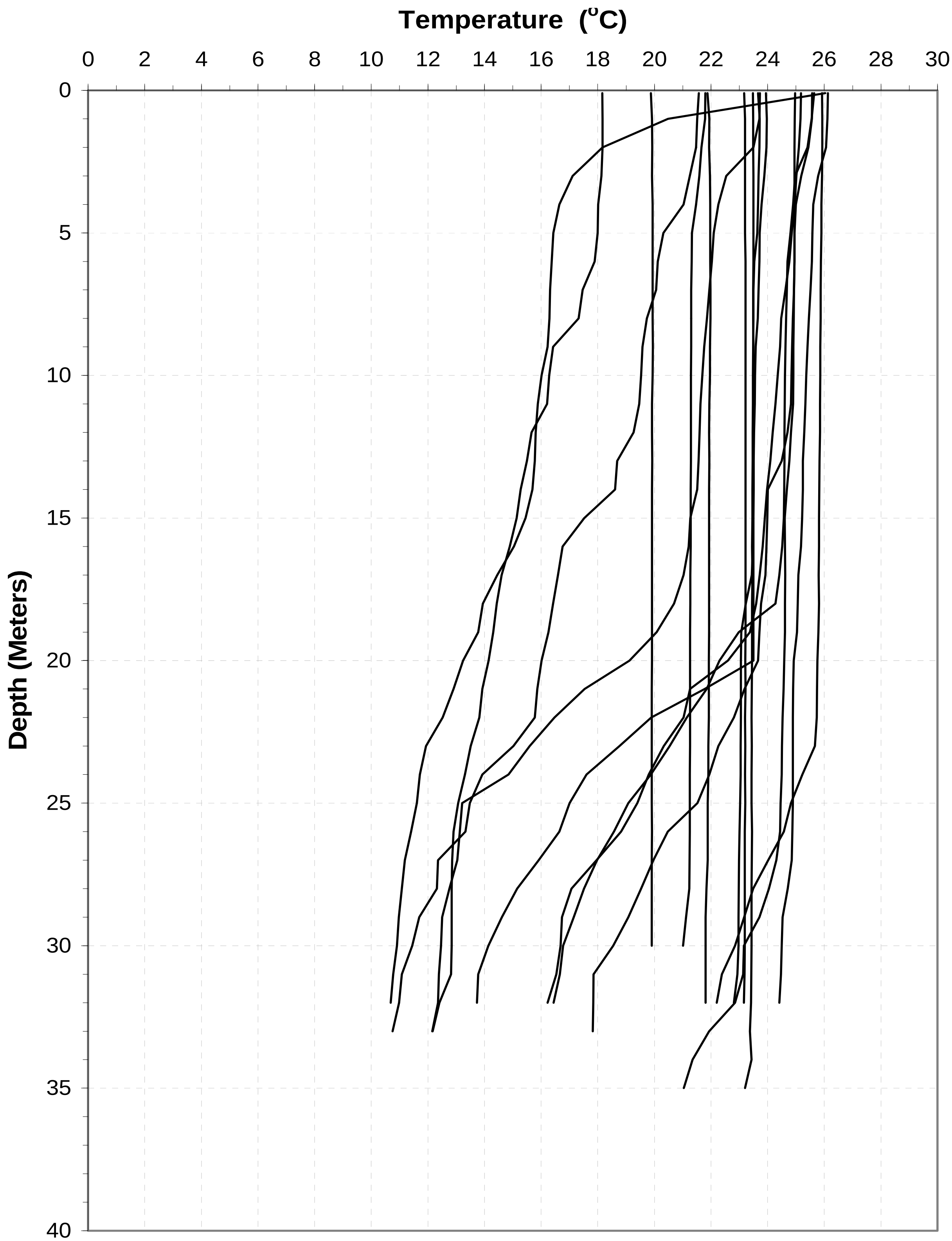


Plate 283. Temperature depth profiles for Lake Francis Case generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., site FTRLK0880A) during the summer months over the 5-year period of 2005 to 2009.

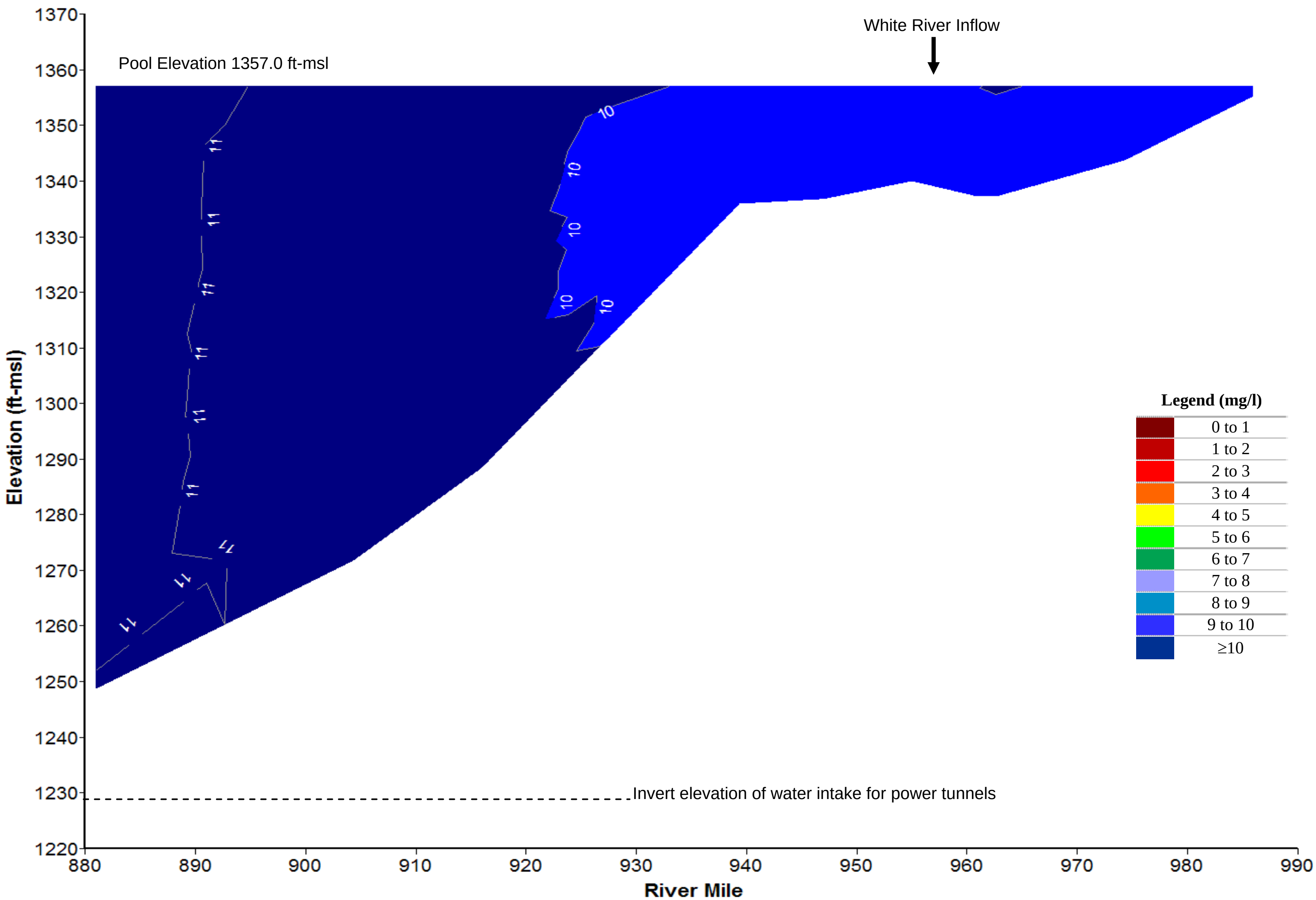


Plate 284. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Francis Case based on depth-profile dissolved oxygen concentrations measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on May 12, 2009.

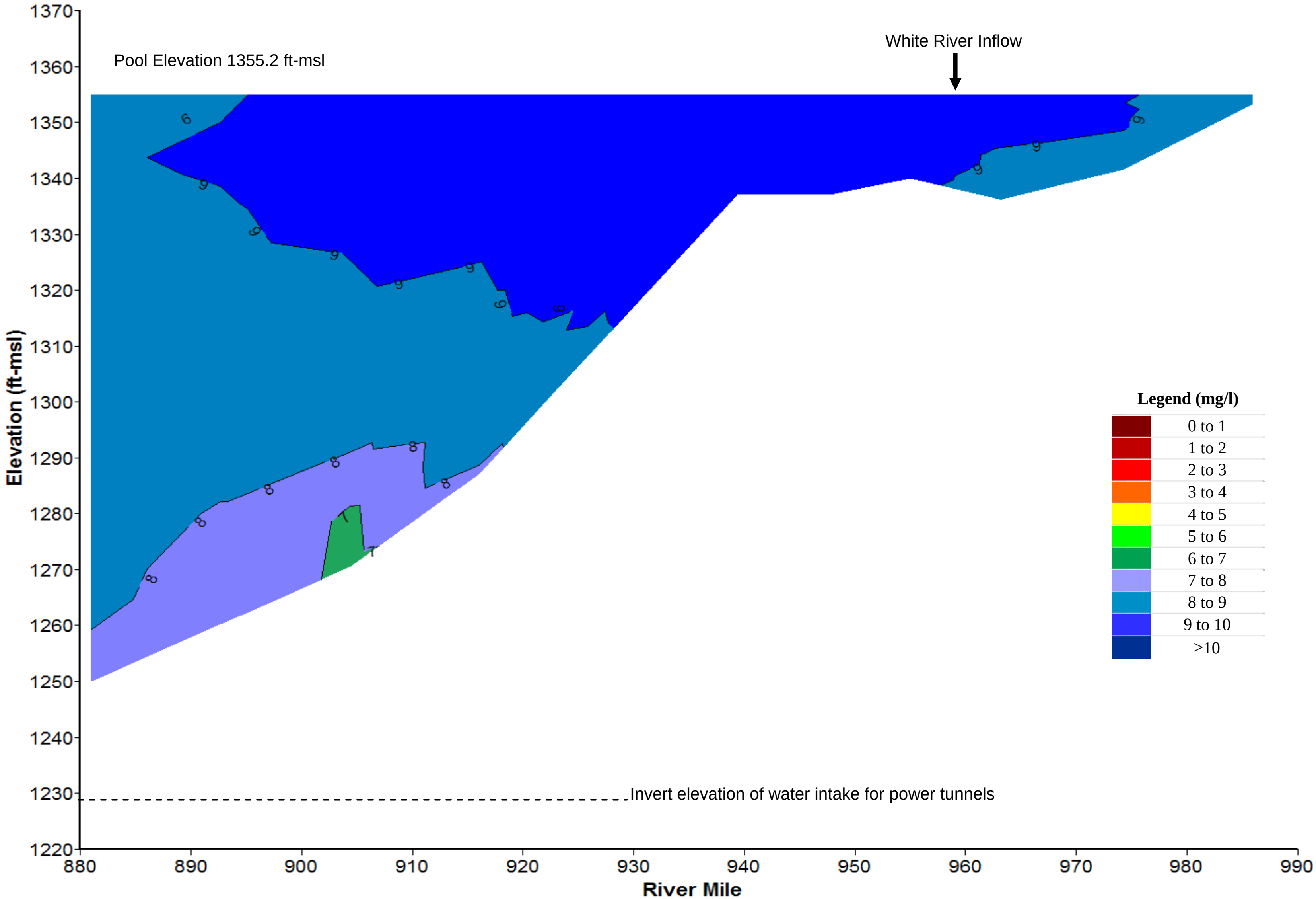


Plate 285. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Francis Case based on depth-profile dissolved oxygen concentrations measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on June 17, 2009.

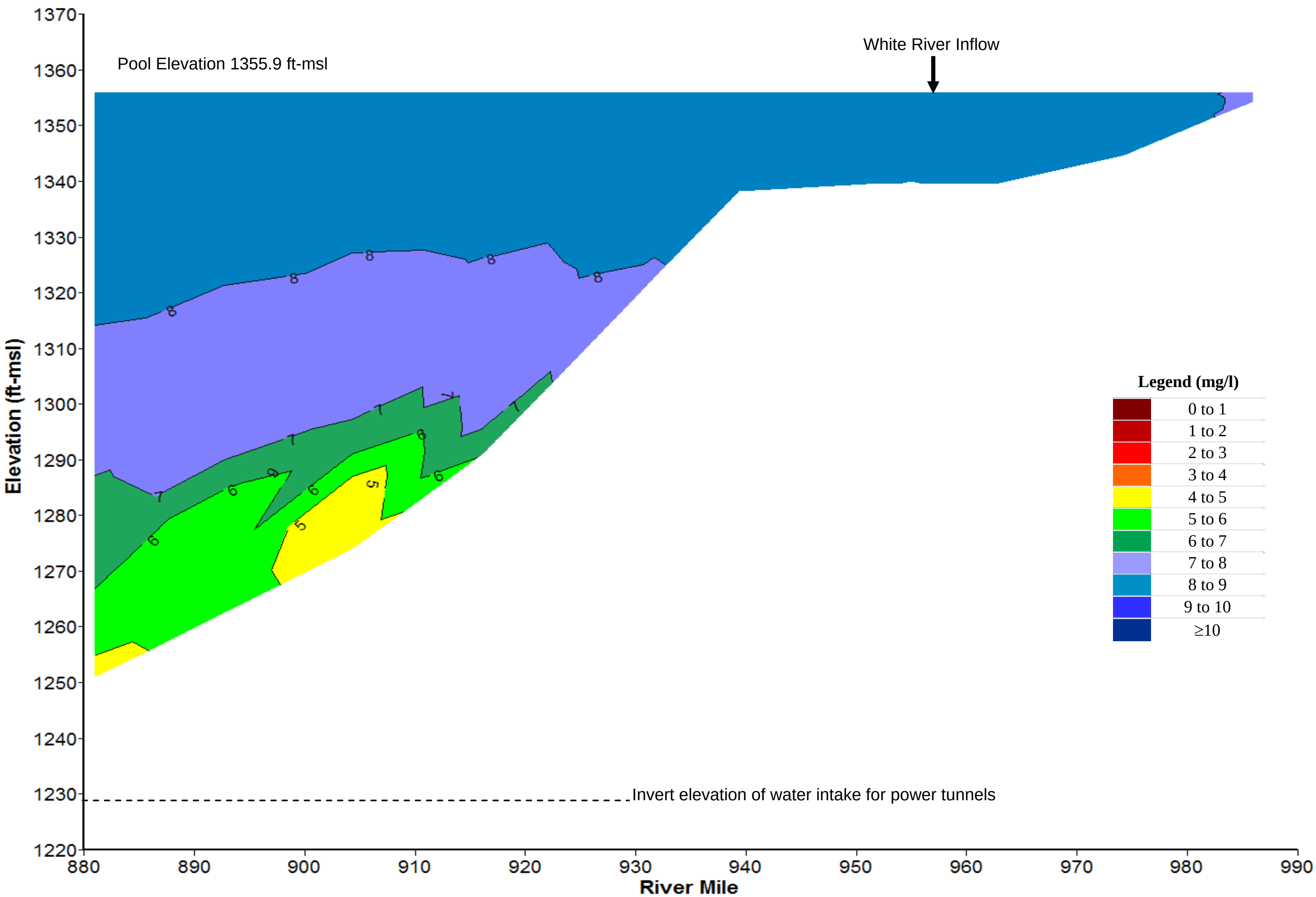


Plate 286. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Francis Case based on depth-profile dissolved oxygen concentrations measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on July 15, 2009.

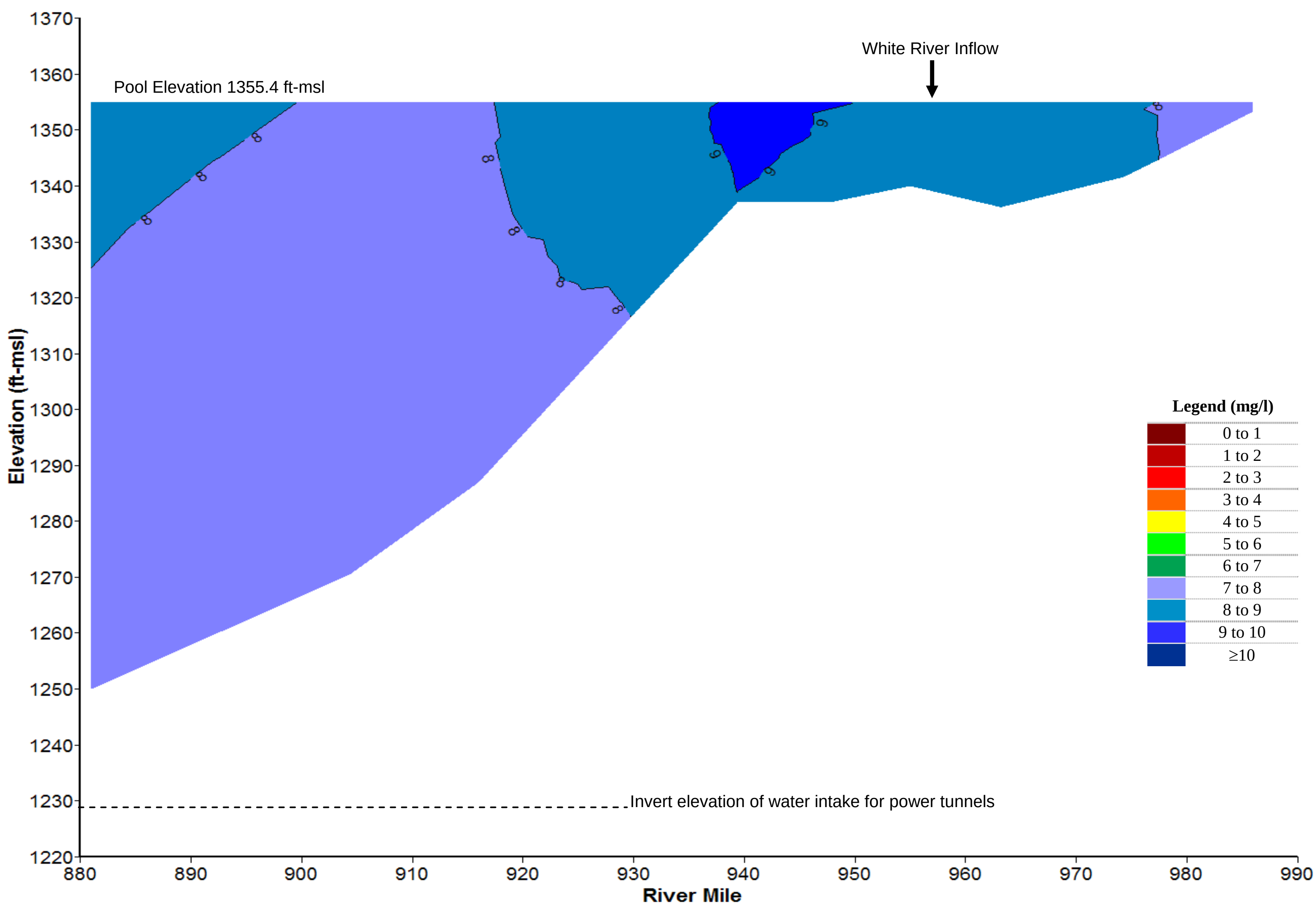


Plate 287. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Francis Case based on depth-profile dissolved oxygen concentrations measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on August 25, 2009.

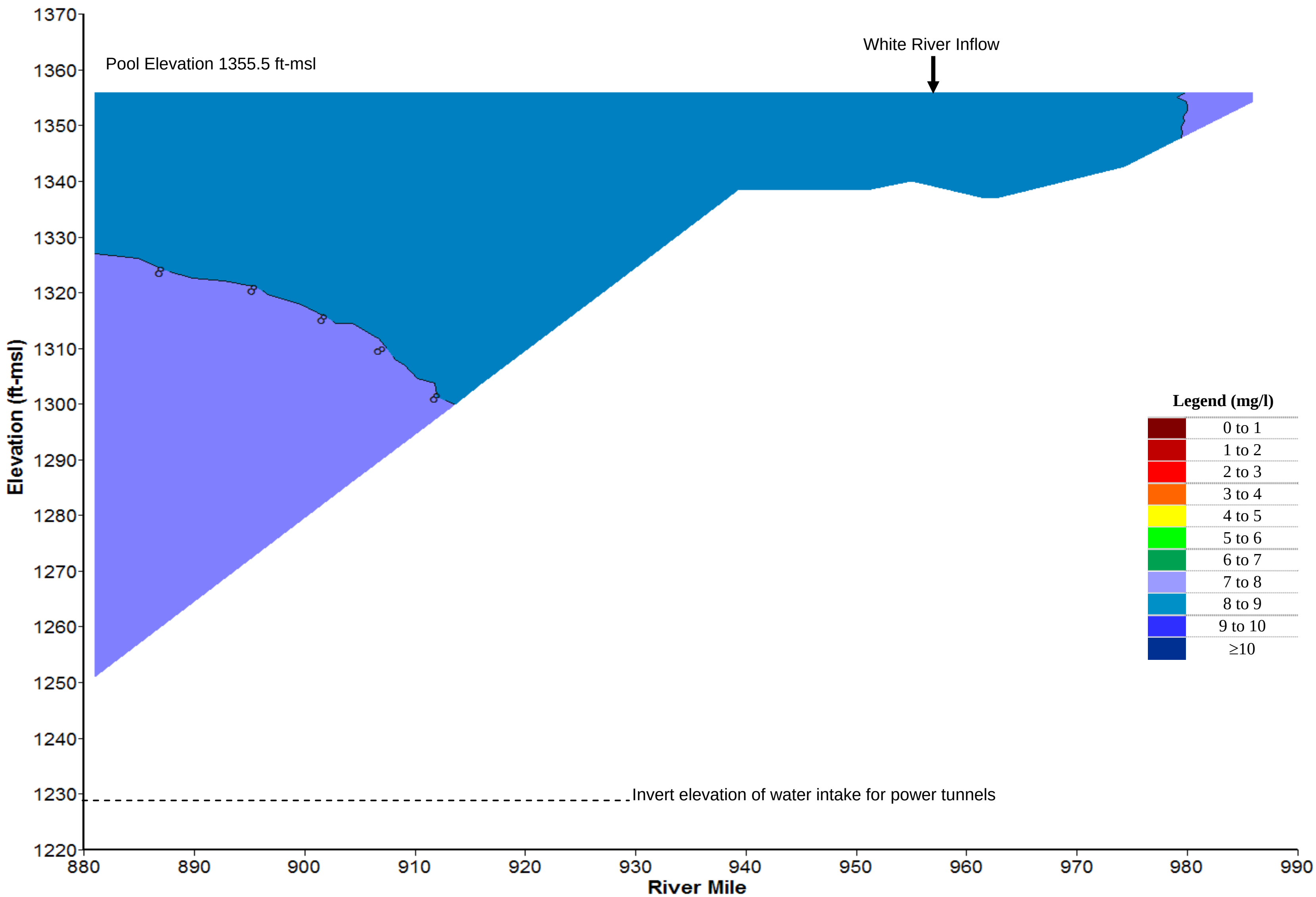


Plate 288. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Francis Case based on depth-profile dissolved oxygen concentrations measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on September 17, 2009.

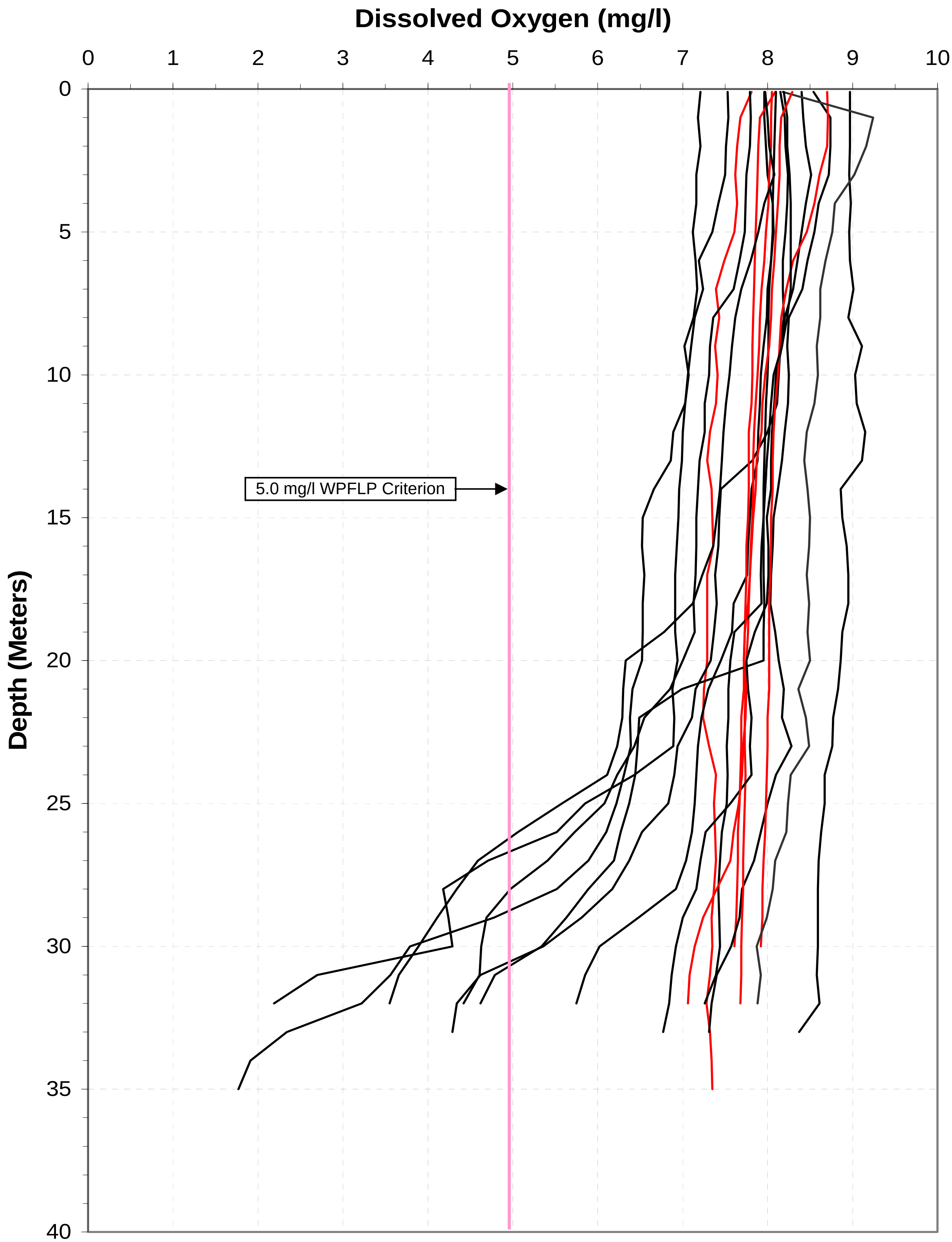


Plate 289. Dissolved oxygen depth profiles for Lake Francis Case generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., site FTRLK0880A) during the summer months over the 5-year period of 2005 to 2009.
(Note: Red profile plots were measured in the month of September.)

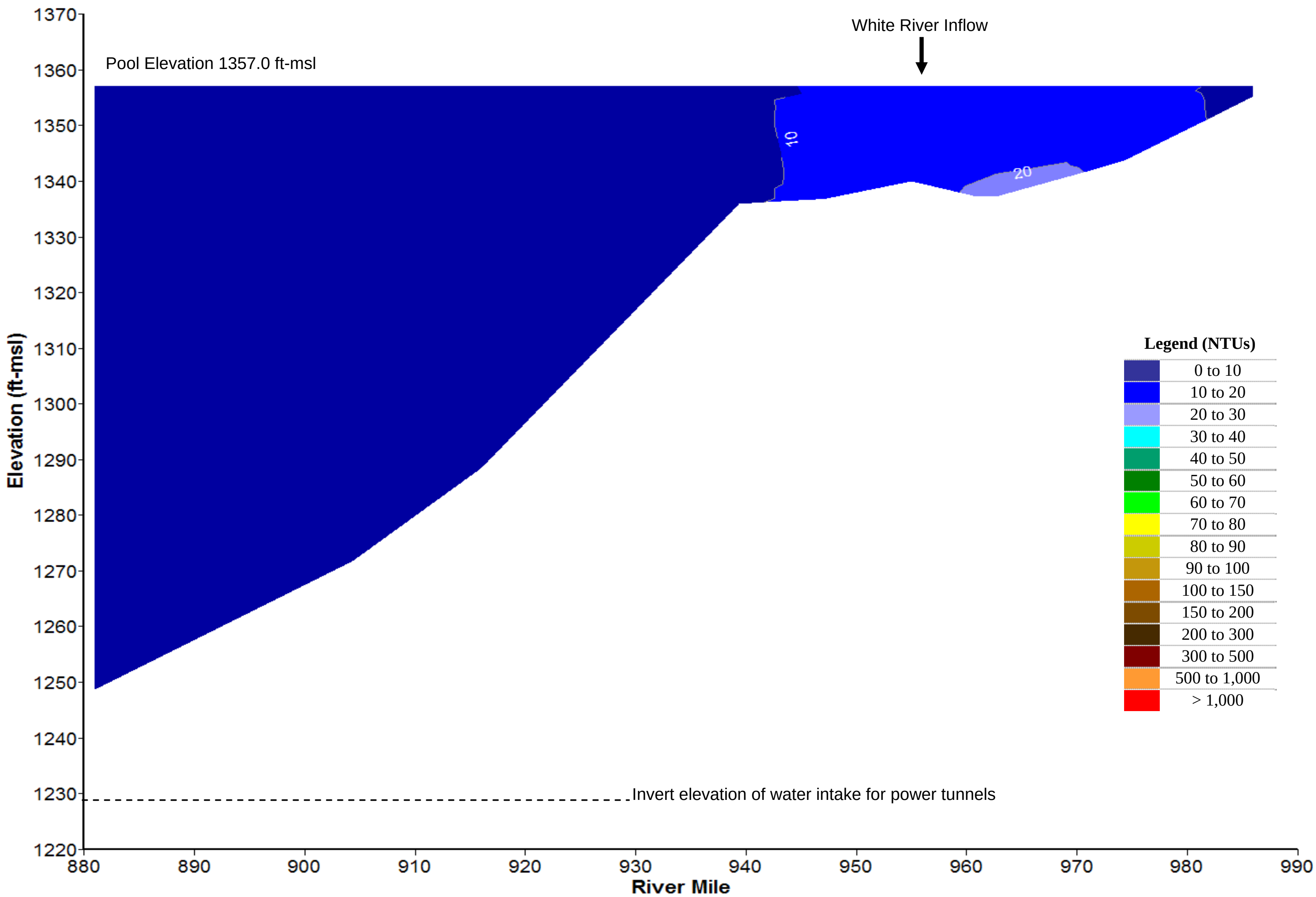


Plate 290. Longitudinal turbidity (NTU) contour plot of Lake Francis Case based on depth-profile turbidity levels measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on May 12, 2009.

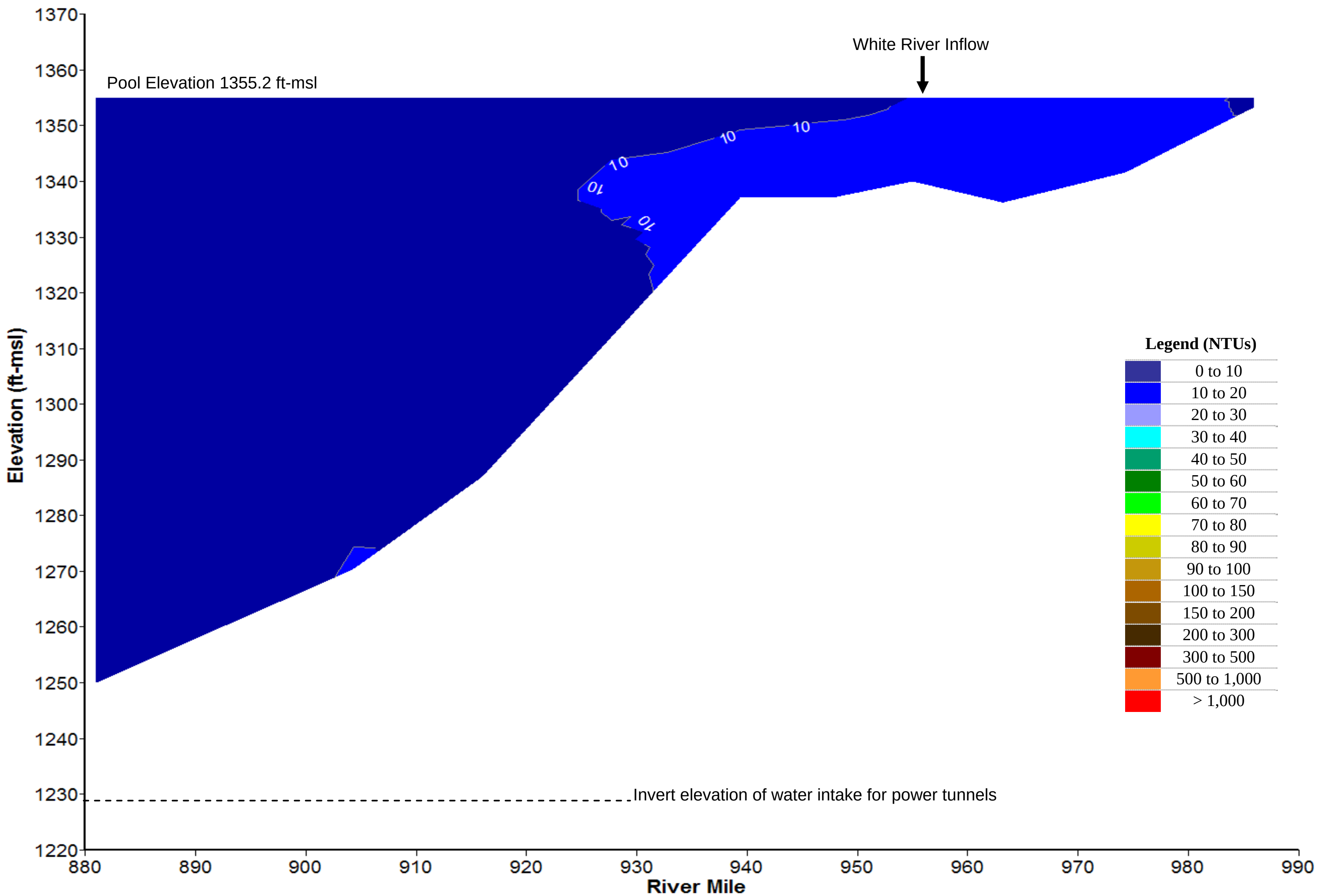


Plate 291. Longitudinal turbidity (NTU) contour plot of Lake Francis Case based on depth-profile turbidity levels measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on June 17, 2009.

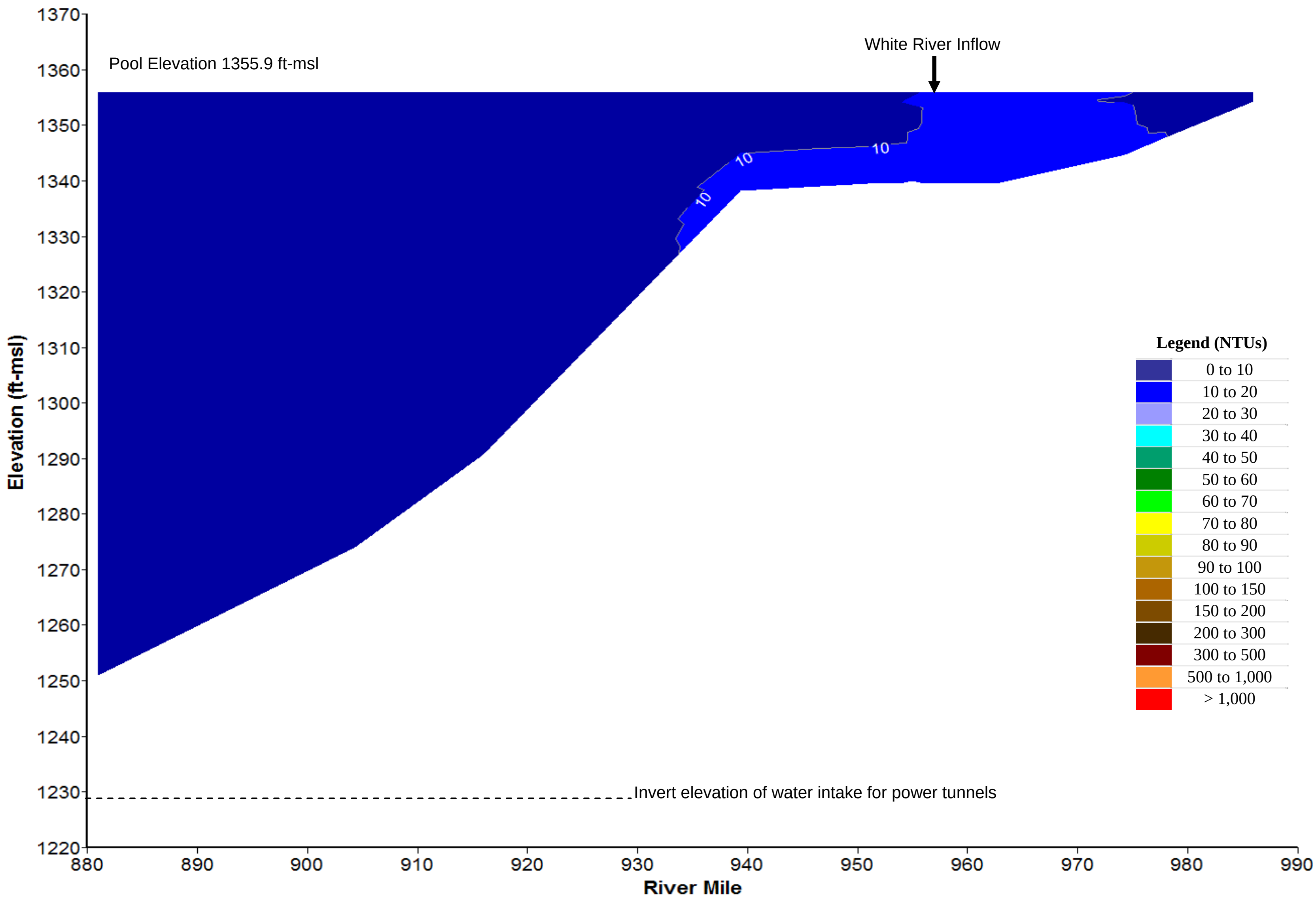


Plate 292. Longitudinal turbidity (NTU) contour plot of Lake Francis Case based on depth-profile turbidity levels measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on July 15, 2009.

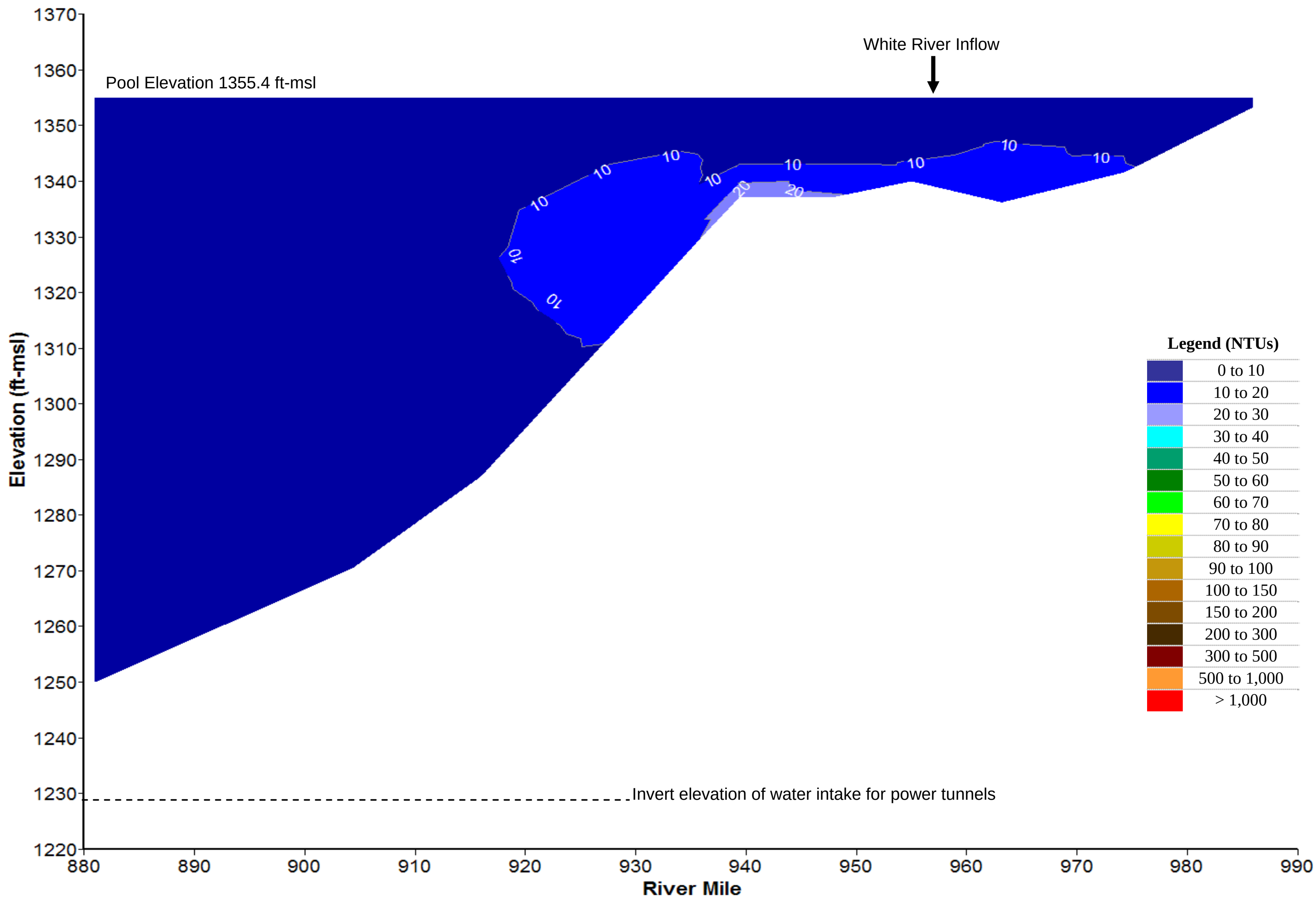


Plate 293. Longitudinal turbidity (NTU) contour plot of Lake Francis Case based on depth-profile turbidity levels measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on August 25, 2009.

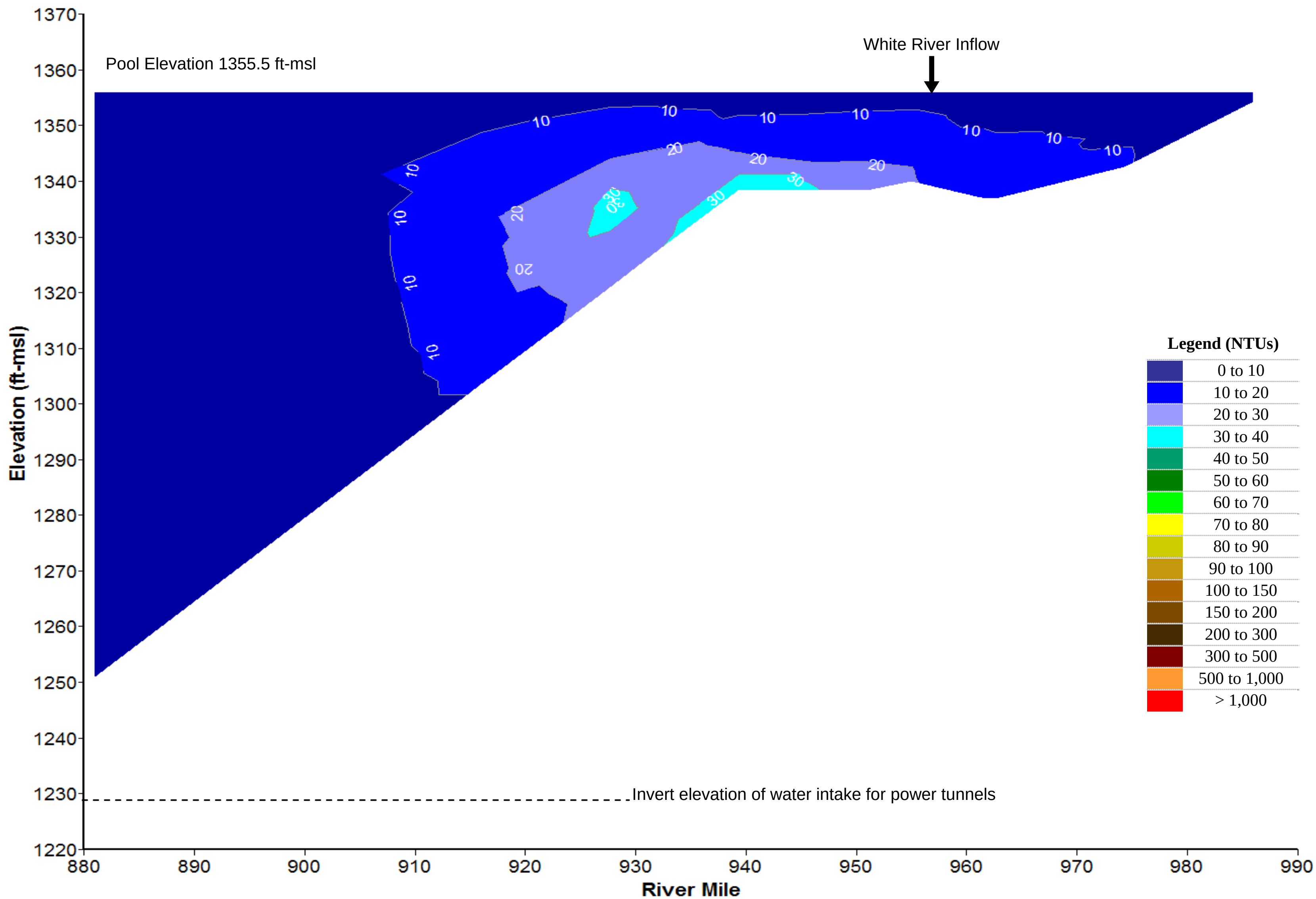


Plate 294. Longitudinal turbidity (NTU) contour plot of Lake Francis Case based on depth-profile turbidity levels measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on September 17, 2009.

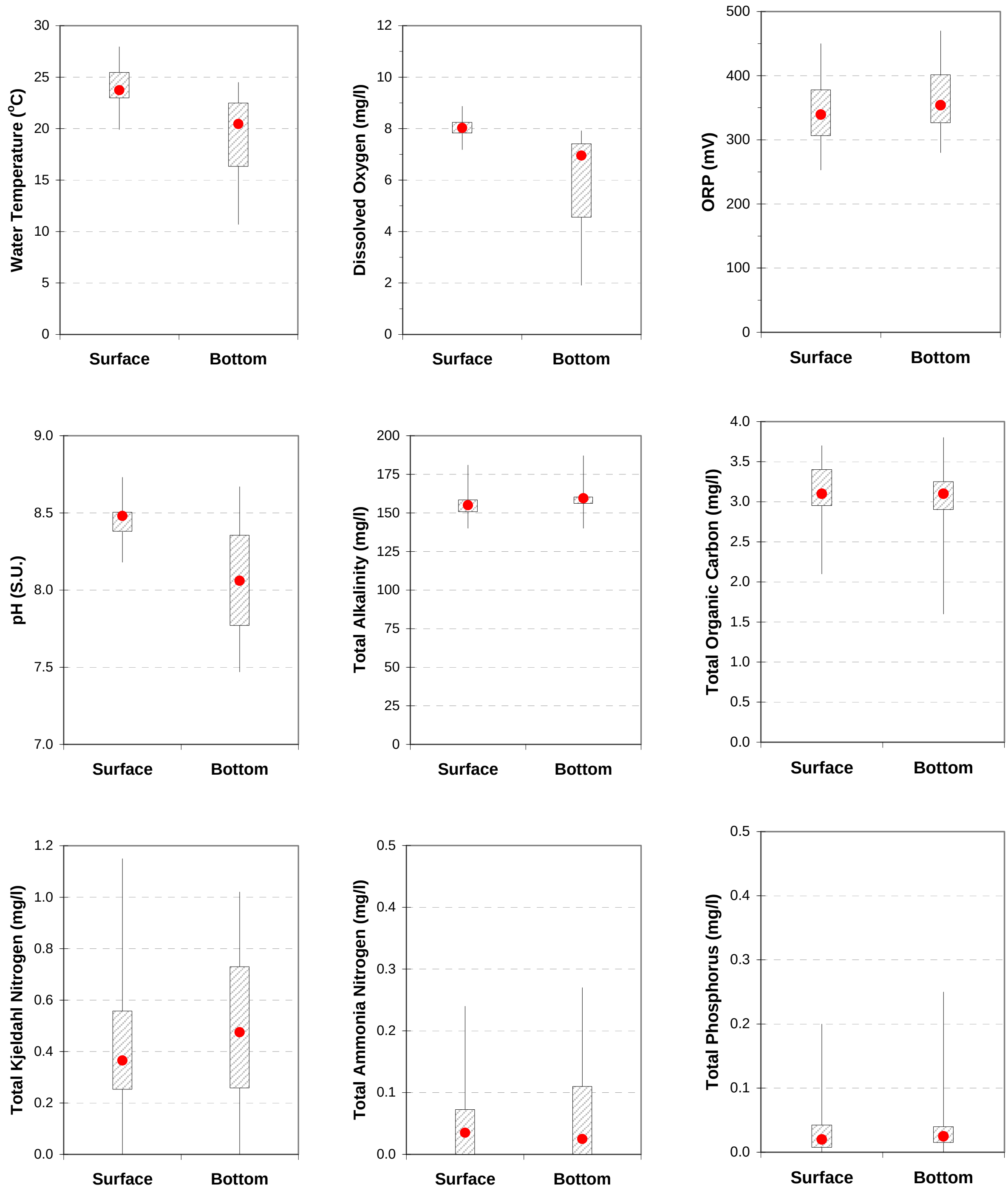


Plate 295. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Lake Francis Case at site FTRLK0880A during the summer months of the 5-year period 2005 through 2009.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 296. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Francis Case at site FTRLK0880A during the 5-year period 2005 through 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
May 2005	1,277,161,733	12	0.97	6	0.02	0	-----	2	0.01	4	<0.01	0	-----	0	-----	1.60
Jun 2005	12,054,751	4	0.41	4	0.19	0	-----	1	0.30	3	0.10	0	-----	0	-----	1.84
Jul 2005	103,882,588	6	0.91	2	<0.01	1	0.06	1	<0.01	3	0.02	0	-----	0	-----	1.43
Aug 2005	131,927,592	5	0.77	4	0.07	1	<0.01	2	0.09	0	-----	1	0.04	1	0.04	1.57
Sep 2005	20,963,108	3	0.15	1	0.01	0	-----	1	0.18	7	0.65	0	-----	0	-----	1.54
May 2006	1,511,202,710	6	1.00	2	<0.01	0	-----	1	<0.01	0	-----	0	-----	0	-----	0.73
Jun 2006	217,211,152	7	0.80	6	0.09	1	0.09	1	0.02	1	<0.01	0	-----	0	-----	1.44
Jul 2006	39,547,409	7	0.88	5	0.08	0	-----	1	0.02	3	0.02	0	-----	1	<0.01	1.44
Aug 2006	250,444,849	5	0.74	7	0.11	2	0.09	1	0.01	1	<0.01	1	0.03	1	0.03	1.57
Sep 2006	391,168,130	6	0.81	11	0.11	0	-----	1	0.02	3	0.01	1	0.03	1	0.01	1.88
May 2007	1,128,309,549	5	0.95	1	0.01	1	<0.01	1	0.02	0	-----	2	0.02	0	-----	1.10
Jun 2007	249,294,812	3	0.38	4	0.41	1	<0.01	1	0.21	0	-----	0	-----	0	-----	1.25
Jul 2007	101,717,269	8	0.61	8	0.15	0	-----	1	0.10	1	0.04	1	0.10	0	-----	1.83
Aug 2007	312,786,957	8	0.39	8	0.03	2	0.01	2	0.03	3	<0.01	1	0.54	1	<0.01	1.41
Sep 2007	228,330,946	7	0.70	11	0.13	0	-----	1	0.06	4	0.03	1	0.04	1	0.04	2.14
May 2008	784,108,007	10	1.00	3	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----	1.14
Jun 2008	1,096,885,699	6	0.97	4	<0.01	2	0.01	1	0.02	1	<0.01	0	-----	0	-----	1.04
Jul 2008	7,177	3	0.06	0	-----	0	-----	1	0.94	1	<0.01	0	-----	0	-----	0.27
Aug 2008	13,678,405	2	0.02	5	0.50	0	-----	1	0.35	1	<0.01	1	0.13	0	-----	1.73
Sep 2008	376,464,061	6	0.80	13	0.05	0	-----	2	0.10	4	0.01	1	0.01	3	0.03	1.63
May 2010	1,561,093,101	9	0.77	4	0.01	1	<0.01	2	0.21	1	<0.01	0	-----	1	0.01	1.56
Jun 2010	534,072,467	7	0.03	7	0.44	0	-----	2	0.51	1	0.01	0	-----	0	-----	1.16
Jul 2010	463,407,098	9	0.14	10	0.12	1	0.01	2	0.68	1	0.02	2	0.04	1	<0.01	1.32
Aug 2010	2,095,582,118	9	0.07	12	0.13	2	0.18	1	0.04	2	0.01	2	0.54	2	0.02	1.70
Sep 2010	2,177,840,974	10	0.89	5	0.06	0	-----	1	0.03	2	0.01	1	<0.01	1	<0.01	1.39
Mean*	**603,165,706**	**6.5**	**0.61**	**5.7**	**0.11**	**0.6**	**0.04**	**1.3**	**0.16**	**1.9**	**0.05**	**0.6**	**0.13**	**0.6**	**0.02**	**1.43**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 297. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Francis Case at site FTRLK0911DW during the 4-year period 2006 through 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2006	69,931,419	5	0.44	7	0.36	2	0.08	1	0.04	1	0.06	1	0.03	0	-----	2.17
Jul 2006	98,641,374	2	0.34	5	0.13	0	-----	1	0.11	3	0.16	1	0.27	0	-----	1.86
Aug 2006	133,306,055	5	0.11	12	0.44	1	0.01	1	0.14	4	0.14	1	0.15	1	0.02	2.71
Sep 2006	83,623,877	10	0.32	15	0.43	0	-----	1	0.10	6	0.02	1	0.12	0	-----	2.59
Jun 2007	1,697,405,287	6	0.89	8	0.06	2	0.01	1	0.03	0	-----	1	0.01	0	-----	1.03
Jul 2007	529,054,652	6	0.04	7	0.02	1	0.01	1	0.02	3	0.88	1	0.04	0	----	0.73
Aug 2007	423,785,980	6	0.93	9	0.02	3	<0.01	2	0.01	3	<0.01	1	0.05	0	-----	1.09
Sep 2007	1,013,742,743	8	0.95	12	0.02	1	<0.01	2	<0.01	5	0.01	1	0.01	1	0.01	1.21
Jun 2008	644,247,513	8	0.95	11	0.01	1	0.01	1	0.02	0	-----	0	-----	0	-----	1.07
Jul 2008	295,300	4	0.87	6	0.02	1	<0.01	1	0.07	2	<0.01	1	0.04	0	-----	1.07
Aug 2008	131,718,414	6	0.62	6	0.01	0	-----	1	0.05	3	0.32	1	0.01	0	-----	1.41
Sep 2008	425,420,567	5	0.85	9	0.03	1	<0.01	2	0.07	6	0.02	2	0.02	1	<0.01	1.38
May 2009	679,955,812	13	0.53	4	0.03	0	-----	2	0.44	1	<0.01	1	0.01	0	-----	1.64
Jun 2009	2,000,418,443	4	0.38	1	<0.01	2	0.01	2	0.47	1	<0.01	1	0.14	0	-----	1.46
Jul 2009	151,866,229	9	0.54	10	0.10	2	0.03	2	0.19	3	<0.01	1	0.13	0	-----	1.81
Aug 2009	733,340,685	9	0.18	14	0.17	1	<0.01	2	0.51	4	0.05	1	0.08	2	0.01	1.99
Sep 2009	655,427,215	7	0.02	13	0.04	1	<0.01	1	0.59	6	0.34	2	0.01	2	0.01	1.53
Mean*	**557,187,151**	**6.6**	**0.53**	**8.8**	**0.12**	**1.1**	**0.01**	**1.4**	**0.17**	**3.0**	**0.13**	**1.1**	**0.07**	**0.4**	**0.01**	**1.57**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 298. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Francis Case at site FTRLK0940DW during the 4-year period 2006 through 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2006	518,893,912	11	0.92	9	0.05	0	-----	0	-----	1	0.03	0	-----	0	-----	1.06
Jul 2006	119,552,113	11	0.81	8	0.07	1	<0.01	0	-----	1	0.06	1	0.05	1	0.01	1.77
Aug 2006	320,031,467	12	0.72	15	0.12	1	0.01	1	<0.01	5	0.14	1	0.01	1	<0.01	2.86
Sep 2006	365,369,612	18	0.83	10	0.11	1	0.03	0	-----	0	-----	1	0.04	0	-----	2.77
Jun 2007	7,768,787,921	8	0.91	10	0.03	2	0.02	1	0.01	5	0.03	1	0.01	0	-----	0.80
Jul 2007	583,012,381	12	0.50	8	0.01	0	-----	1	0.01	3	0.47	1	0.01	0	-----	1.69
Aug 2007	210,296,968	10	0.48	11	0.22	1	<0.01	2	0.06	3	0.12	2	0.11	0	-----	2.72
Jun 2008	145,687,021	10	0.84	9	0.05	2	0.04	1	0.06	1	<0.01	0	-----	0	-----	1.40
Jul 2008	745,624	5	0.86	6	0.07	1	<0.01	1	0.01	6	0.06	2	<0.01	2	<0.01	1.28
Aug 2008	217,934,376	11	0.95	4	<0.01	0	-----	1	<0.01	2	<0.01	1	0.01	3	0.01	1.27
May 2009	2,413,863,924	13	0.89	5	0.02	2	<0.01	2	0.09	2	<0.01	1	<0.01	1	<0.01	1.23
Jun 2009	2,883,888,916	11	0.95	7	0.01	1	0.02	1	0.02	1	<0.01	0	-----	0	-----	0.46
Jul 2009	932,155,830	7	0.83	6	0.05	1	0.04	1	0.08	0	-----	1	<0.01	0	-----	1.33
Aug 2009	876,317,753	10	0.21	15	0.06	2	0.15	2	0.39	6	0.04	2	0.15	2	<0.01	2.21
Sep 2009	509,195,961	10	0.22	11	0.09	2	0.05	1	0.46	5	0.15	2	0.03	2	0.01	2.11
Mean*	**1,191,048,919**	**10.6**	**0.73**	**8.9**	**0.06**	**1.1**	**0.03**	**1.0**	**0.10**	**2.7**	**0.08**	**1.1**	**0.04**	**0.8**	**<0.01**	**1.66**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 299. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Francis Case at site FTRLK0968DW during the 4-year period 2006 through 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2006	3,042,159,471	9	0.94	9	0.04	1	<0.01	1	<0.01	2	0.01	1	<0.01	0	-----	0.44
Jul 2006	235,103,339	7	0.24	6	0.72	1	<0.01	1	0.01	1	0.03	0	-----	1	<0.01	1.37
Aug 2006	842,613,801	19	0.91	14	0.04	2	<0.01	1	<0.01	6	0.03	1	0.01	1	<0.01	1.80
Sep 2006	270,757,940	17	0.80	11	0.14	1	0.01	1	<0.01	1	<0.01	1	0.04	2	0.01	2.42
Jun 2007	1,073,452,712	5	0.71	11	0.14	2	0.01	1	0.03	1	<0.01	1	0.11	0	-----	1.49
Jul 2007	405,005,185	14	0.42	6	0.02	1	<0.01	1	0.05	1	0.37	1	0.12	0	0.01	2.02
Aug 2007	162,100,006	11	0.55	6	0.03	2	0.02	1	0.01	3	<0.01	1	0.31	2	0.08	2.30
Sep 2007	121,850,078	8	0.73	6	0.03	1	<0.01	1	0.05	5	0.18	0	-----	0	-----	2.15
Jun 2008	1,161,968,310	8	0.96	9	0.01	2	<0.01	1	0.03	1	<0.01	0	-----	0	-----	0.93
Jul 2008	238,272	4	0.86	2	0.01	0	-----	1	0.01	6	0.12	0	-----	0	-----	0.63
Aug 2008	133,462,205	10	0.94	3	0.01	0	-----	1	0.03	3	<0.01	1	0.01	0	-----	1.30
Sep 2008	103,962,738	10	0.86	2	0.02	1	<0.01	2	0.08	1	<0.01	0	-----	3	0.04	1.51
May 2009	2,165,370,105	11	0.85	3	<0.01	0	-----	2	0.14	0	-----	1	0.01	0	-----	0.70
Jun 2009	1,682,998,478	9	0.36	5	0.13	0	-----	2	0.51	0	-----	0	-----	0	-----	1.24
Jul 2009	808,602,20	15	0.60	7	0.13	1	<0.01	2	0.26	0	-----	1	0.01	2	<0.01	1.90
Aug 2009	414,514,599	12	0.29	8	0.04	2	0.01	1	0.05	3	0.02	1	0.59	0	-----	1.71
Sep 2009	455,914,391	10	0.44	12	0.14	1	0.10	2	0.26	3	0.04	1	0.01	2	0.01	2.52
Mean*	**766,966,977**	**10.5**	**0.67**	**7.1**	**0.10**	**1.1**	**0.01**	**1.3**	**0.09**	**2.2**	**0.06**	**0.6**	**0.11**	**0.8**	**0.02**	**1.55**

* Mean percent composition represents the mean when taxa of that division are present.

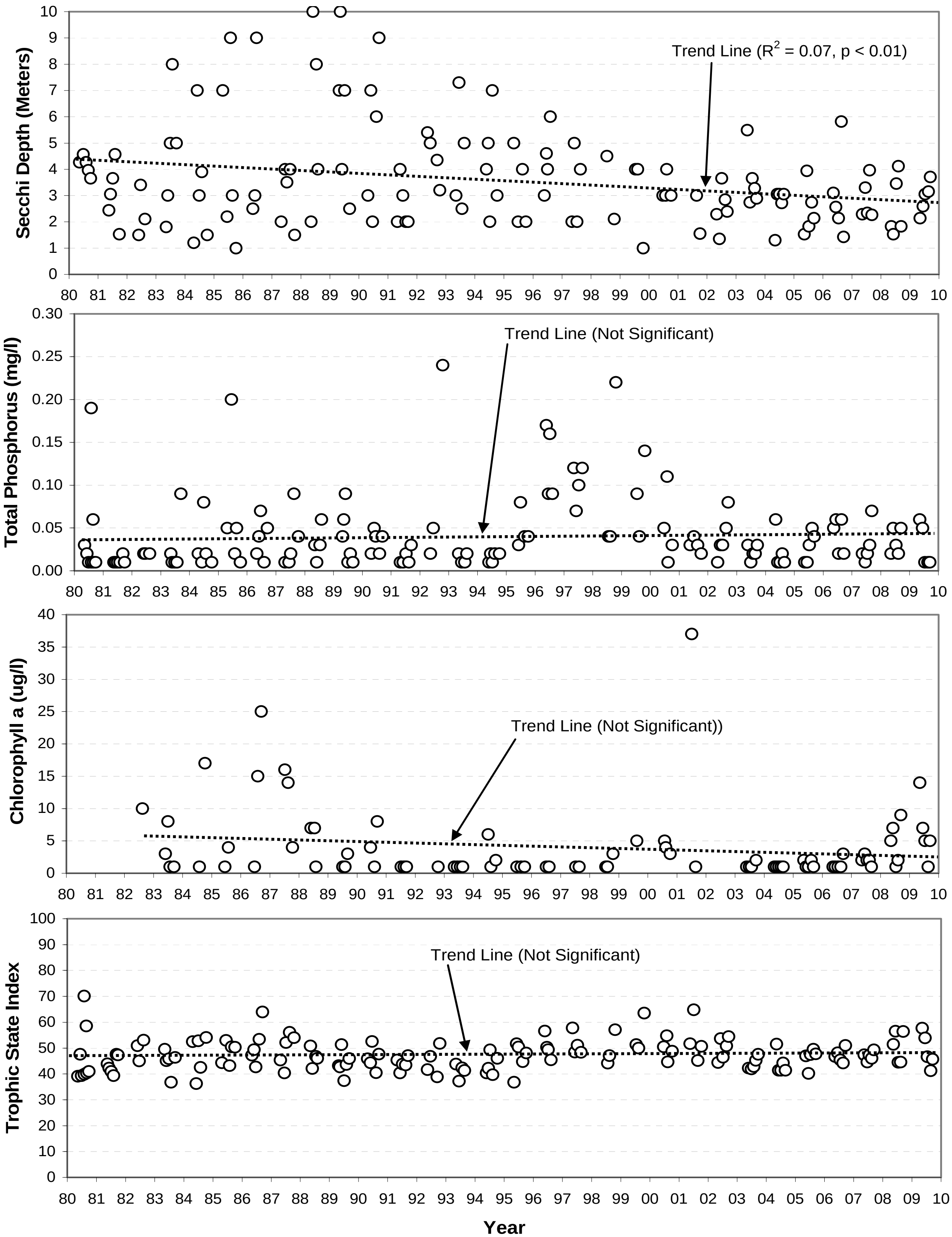


Plate 300. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Lake Francis Case at the near-dam, ambient site (i.e., site FTRLK0880A) over the 30-year period of 1980 through 2009.

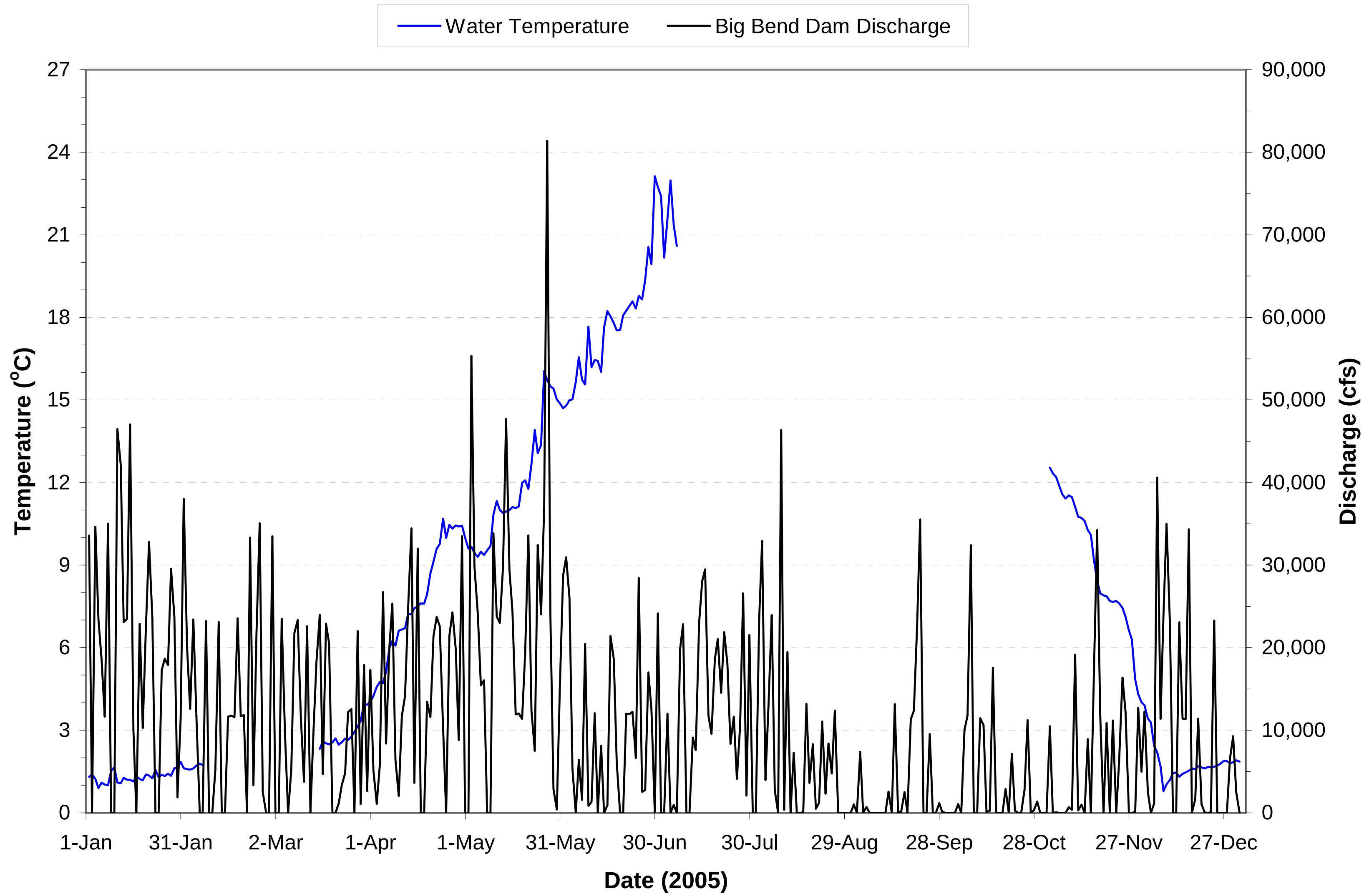


Plate 301. Mean daily water temperature and discharge of the Missouri River at Big Bend Dam (i.e., site BBDPP1) for 2005. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Big Bend Dam.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

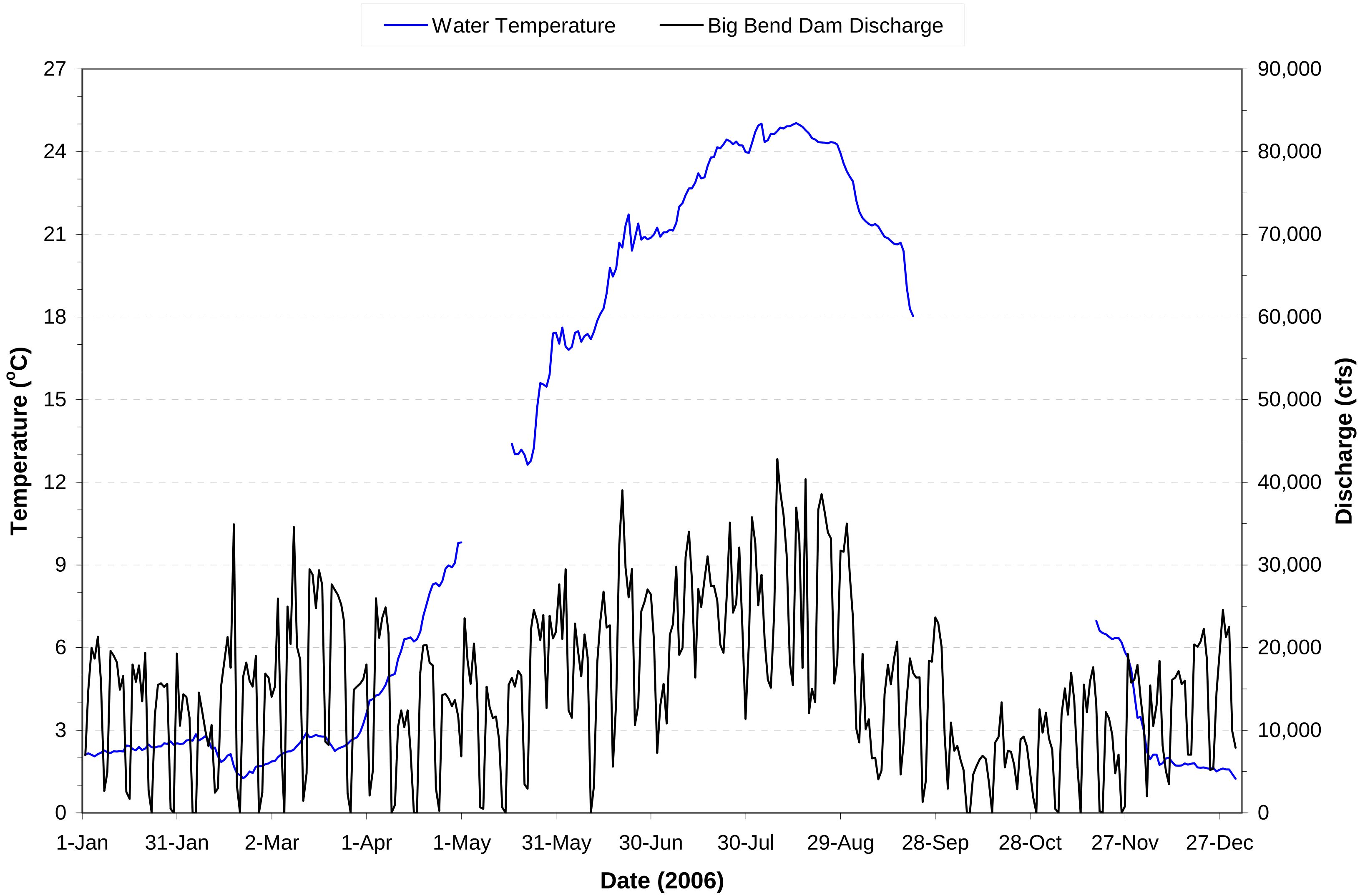


Plate 302. Mean daily water temperature and discharge of the Missouri River at Big Bend Dam (i.e., site BBDPP1) for 2006. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Big Bend Dam.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

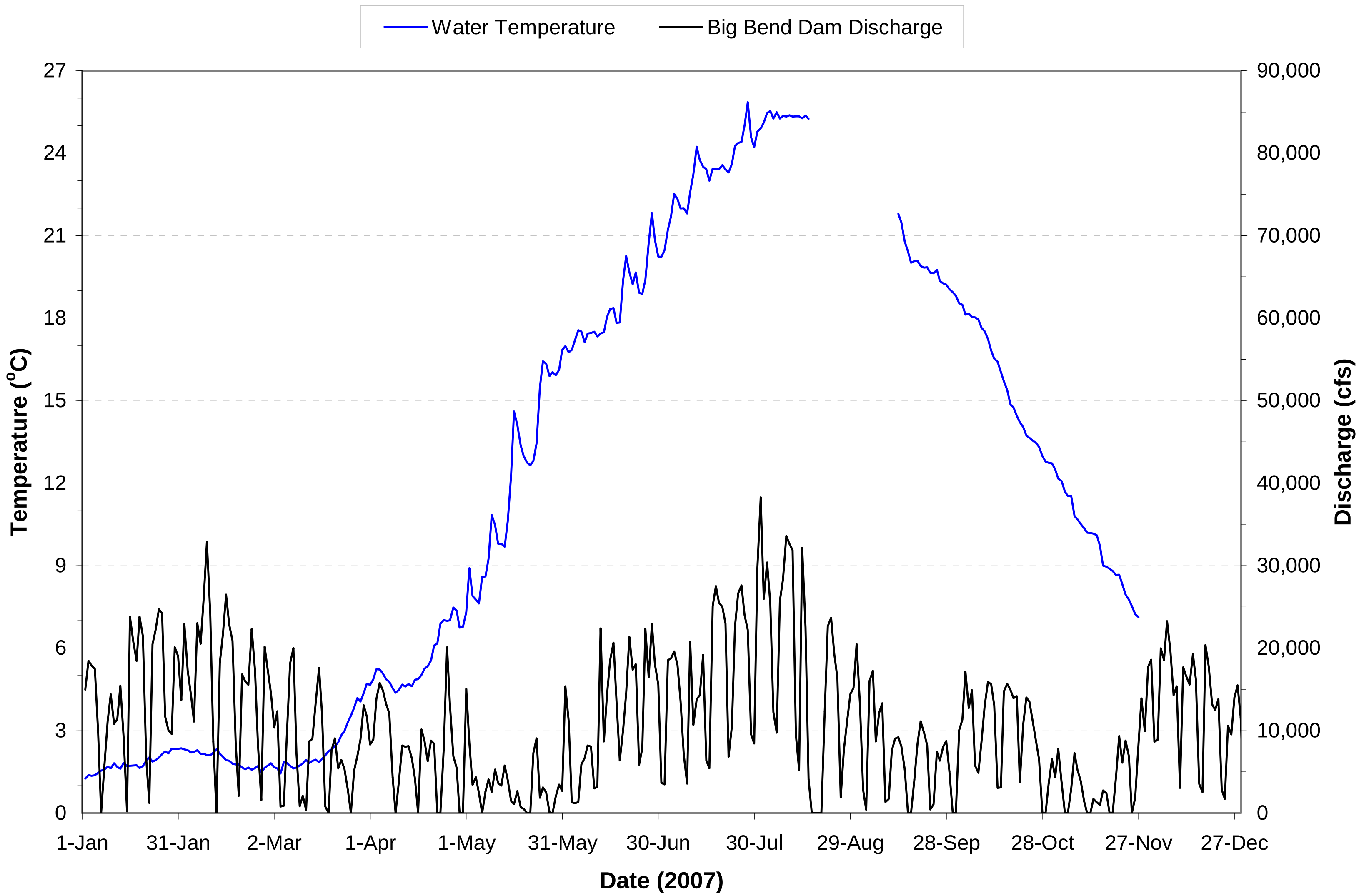


Plate 303. Mean daily water temperature and discharge of the Missouri River at Big Bend Dam (i.e., site BBDPP1) for 2007. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Big Bend Dam.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

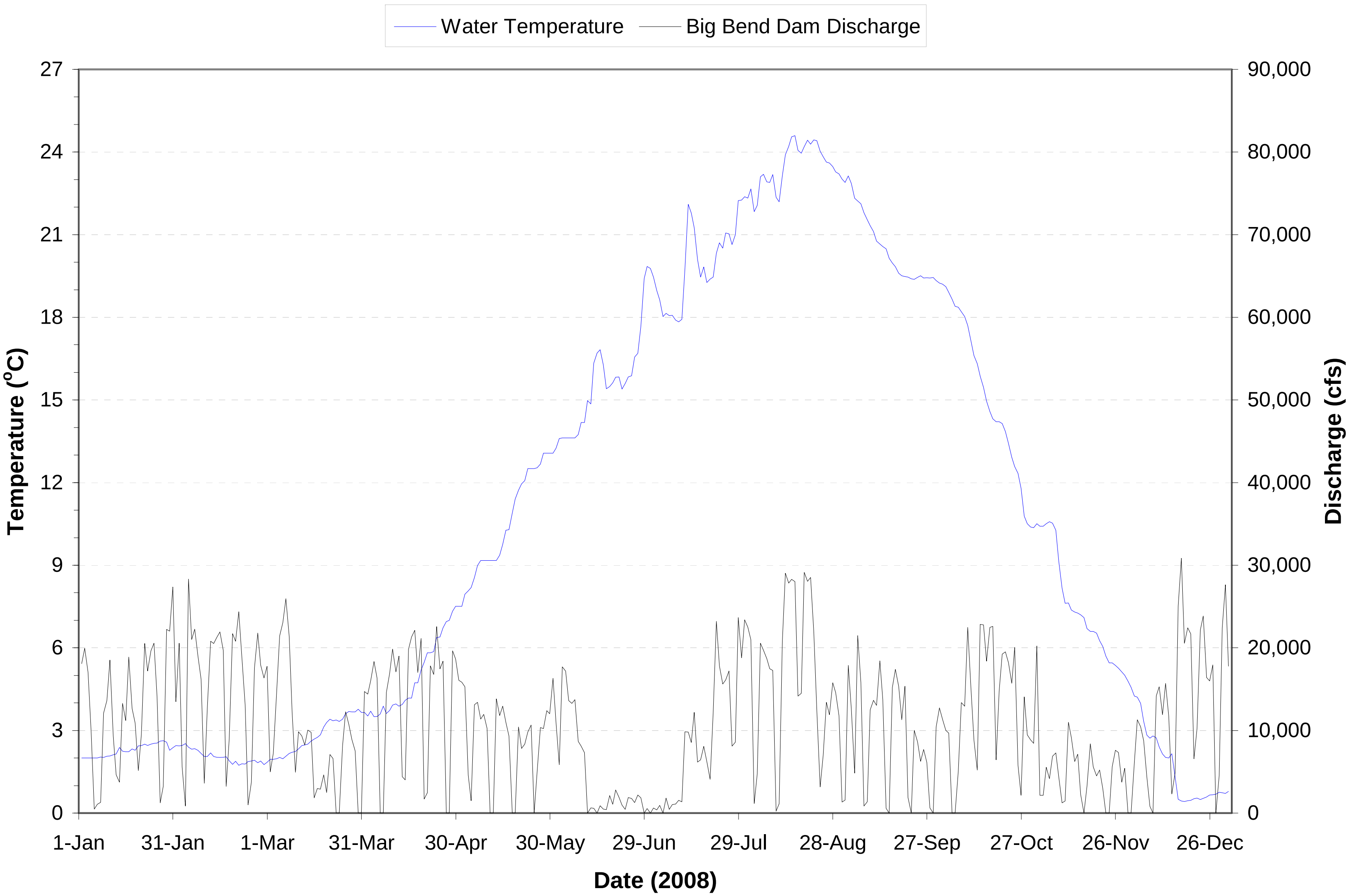


Plate 304. Mean daily water temperature and discharge of the Missouri River at Big Bend Dam (i.e., site BBDPP1) for 2008. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Big Bend Dam.

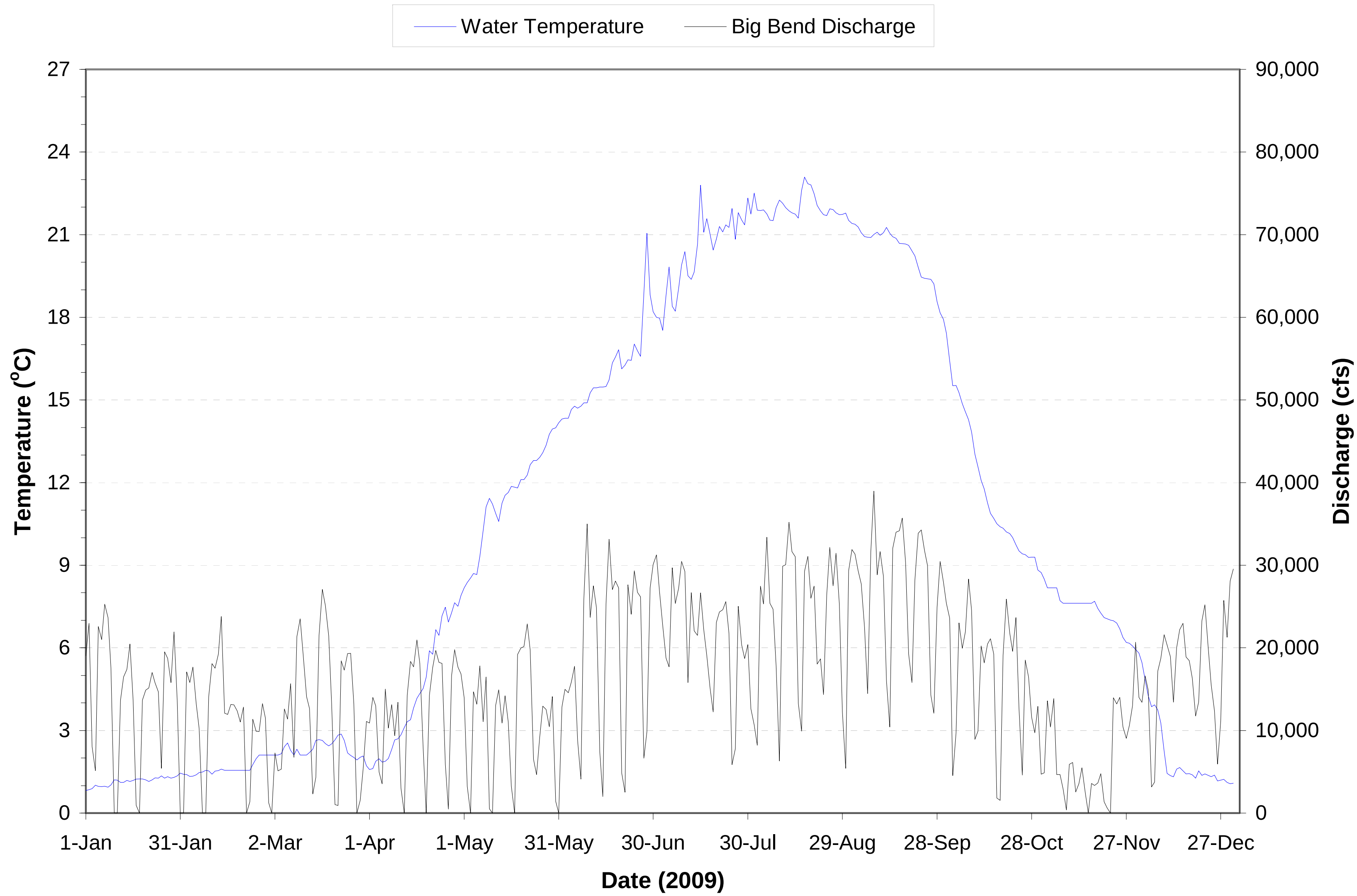


Plate 305. Mean daily water temperature and discharge of the Missouri River at Big Bend Dam (i.e., site BBDPP1) for 2009. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Big Bend Dam.

Plate 306. Summary of water quality conditions monitored on water discharged through Fort Randall Dam (i.e., site FTRPP1) during the 5-year period of 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Dam Discharge (cfs)	1	52	19,533	18,830	0	41,200	-----	-----	-----
Water Temperature (°C)	0.1	50	11.7	10.9	0.6	25.4	27[1,4]	0	0%
Dissolved Oxygen (mg/l)	0.1	50	10.0	10.5	5.2	13.8	5[1,5]	0	0%
Dissolved Oxygen (% Sat.)	0.1	50	92.3	95.4	52.3	104.2	-----	-----	-----
pH (S.U.)	0.1	44	8.3	8.3	7.2	8.7	6.5[1,2,5], 9.0[1,2,4], 9.5[3,4]	0	0%
Specific Conductance (umho/cm)	1	50	702	720	562	772	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	33	362	358	273	458	-----	-----	-----
Turbidity (NTU)	1	31	3	2	0	17	-----	-----	-----
Alkalinity, Total (mg/l)	7	52	164	163	130	191	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	50	3.2	3.1	2.1	5.0	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	40	10	11	0	22	-----	-----	-----
Chloride, Dissolved (mg/l)	1	39	12	12	9	14	438[2,4], 250[2,6]	0	0%
Dissolved Solids, Total (mg/l)	5	52	474	476	314	612	1,750[2,4], 1,000[2,7], 3,500[3,4], 2,000[3,6]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	52	-----	n.d.	n.d.	0.29	4.7 [1,4,7], 1.4 [1,6,7]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	52	0.5	0.3	n.d.	3.6	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	52	-----	n.d.	n.d.	0.41	10[2,4]	0	0%
Nitrogen, Total (mg/l)	0.1	52	0.5	0.3	n.d.	3.6			
Phosphorus, Dissolved (mg/l)	0.02	38	-----	n.d.	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	52	-----	0.02	n.d.	0.25	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	51	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	52	203	207	117	230	875[2,4], 500[2,6]	0	0%
Suspended Solids, Total (mg/l)	4	52	-----	n.d.	n.d.	26	158[1,4], 90[1,6]	0	0%

n.d. = Not detected, b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of commerce and industry waters.
- (4) Daily maximum criterion (monitoring results directly comparable to criterion).
- (5) Daily minimum criterion (monitoring results directly comparable to criterion).
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

Plate 307. Summary of annual metals and pesticide levels monitored on water discharged through Fort Randall Dam (i.e., site FTRPP1) during the 5-year period of 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.[A]	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Aluminum, Total (ug/l)	25	3	104	110	71	130	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	0.6	-----	-----	-----
Antimony, Total (ug/l)	0.5	3	-----	n.d.	n.d.	0.7	5.6[3]	0	0%
Arsenic, Dissolved (ug/l)	1	3	2	2	1	2	340[1], 150[2]	0, 0	0%, 0%
Arsenic, Total (ug/l)	1	3	2	2	1	2	0.018[3]	3	100%
Barium, Dissolved (ug/l)	5	3	33	32	31	36	-----	-----	-----
Barium, Total (ug/l)	5	3	34	33	30	40	-----	-----	-----
Beryllium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Beryllium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	4[3]	0	0%
Cadmium, Dissolved (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	4.4[1], 0.43[2]	0	0%
Cadmium, Total (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	5[3]	0	0%
Chromium, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	n.d.	1,106[1], 144[2]	0	0%
Chromium, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Copper, Dissolved (ug/l)	2	7	-----	n.d.	n.d.	5	29[1], 18[2],	0	0%
Copper, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	1,300[3]	0	0%
Hardness, Total (mg/l)	1	4	225	225	211	239	-----	-----	-----
Iron, Dissolved (ug/l)	40	25	-----	n.d.	n.d.	50	-----	-----	-----
Iron, Total (ug/l)	40	25	119	80	n.d.	1,121	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	154[1], 6.0[2]	0	0%
Lead, Total (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Manganese, Dissolved (ug/l)	2	25	-----	2	n.d.	14	-----	-----	-----
Manganese, Total (ug/l)	2	25	19	17	n.d.	47	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	8	-----	n.d.	n.d.	n.d.	1.4[1]	0	0%
Mercury, Total (ug/l)	0.05	8	-----	n.d.	n.d.	n.d.	0.77[2], 0.05[3]	0	0%
Nickel, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	n.d.	930[1], 103[2]	0	0%
Nickel, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	610[3]	0	0%
Selenium, Total (ug/l)	1	2	2	2	2	2	4.6[2], 170[3]	0	0%
Silver, Dissolved (ug/l)	1	7	-----	n.d.	n.d.	n.d.	13[1]	0	0%
Silver, Total (ug/l)	1	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Total (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	0.24[3]	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	11	233[1,2]	0	0%
Zinc, Total (ug/l)	10	3	-----	n.d.	n.d.	11	7,400[3]	0	0%
Pesticide Scan (ug/l)[D]	0.05	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected, b.d. = Criterion below detection limit.

(A) Results for iron (dissolved and total) and manganese (dissolved and total) include some monthly samples.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Acute (CMC) criterion for the protection of freshwater aquatic life.

(2) Chronic (CCC) criterion for the protection of freshwater aquatic life.

(3) Criterion for the protection of human health.

Note: Some of South Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

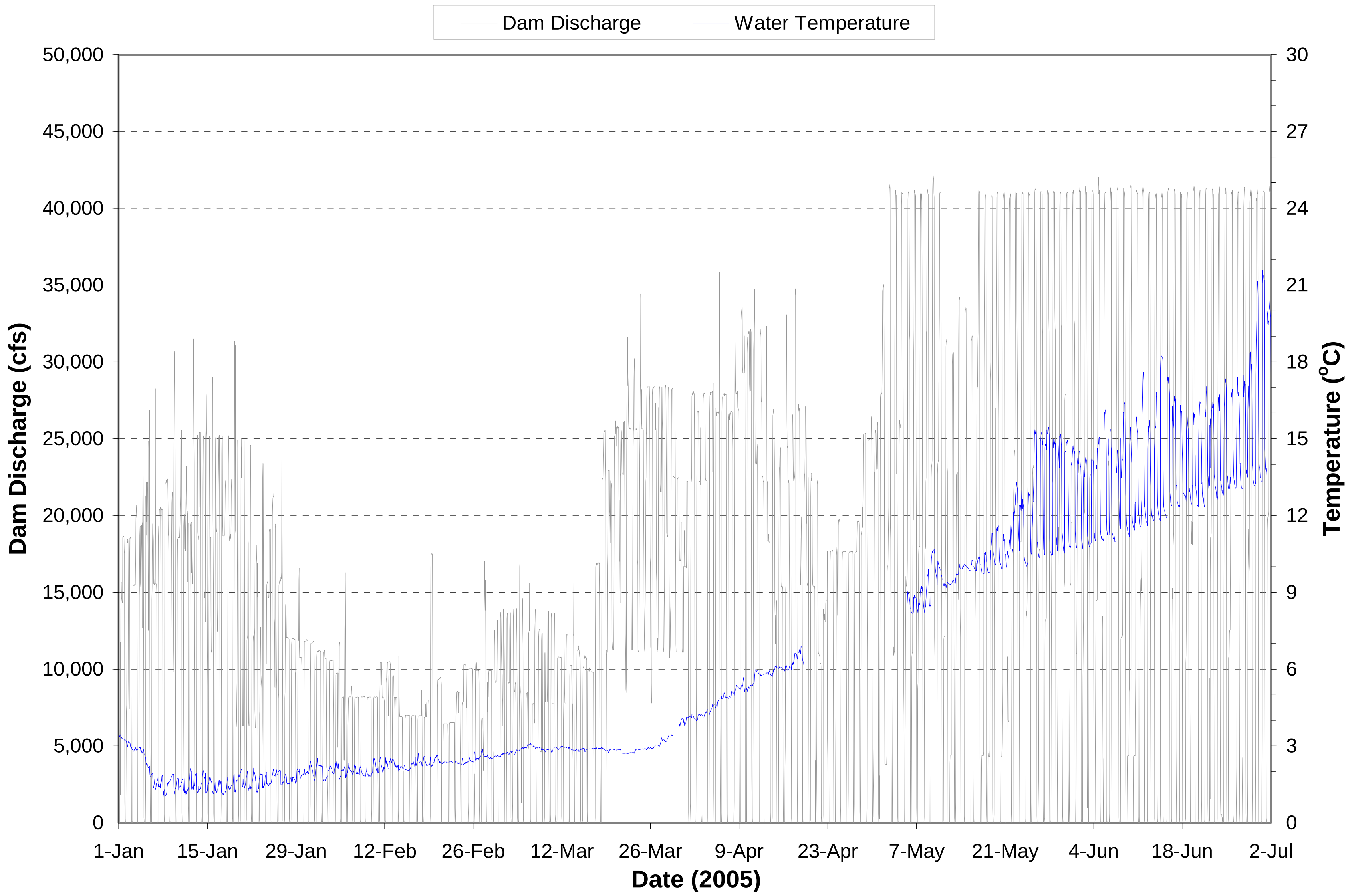


Plate 308. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2005.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

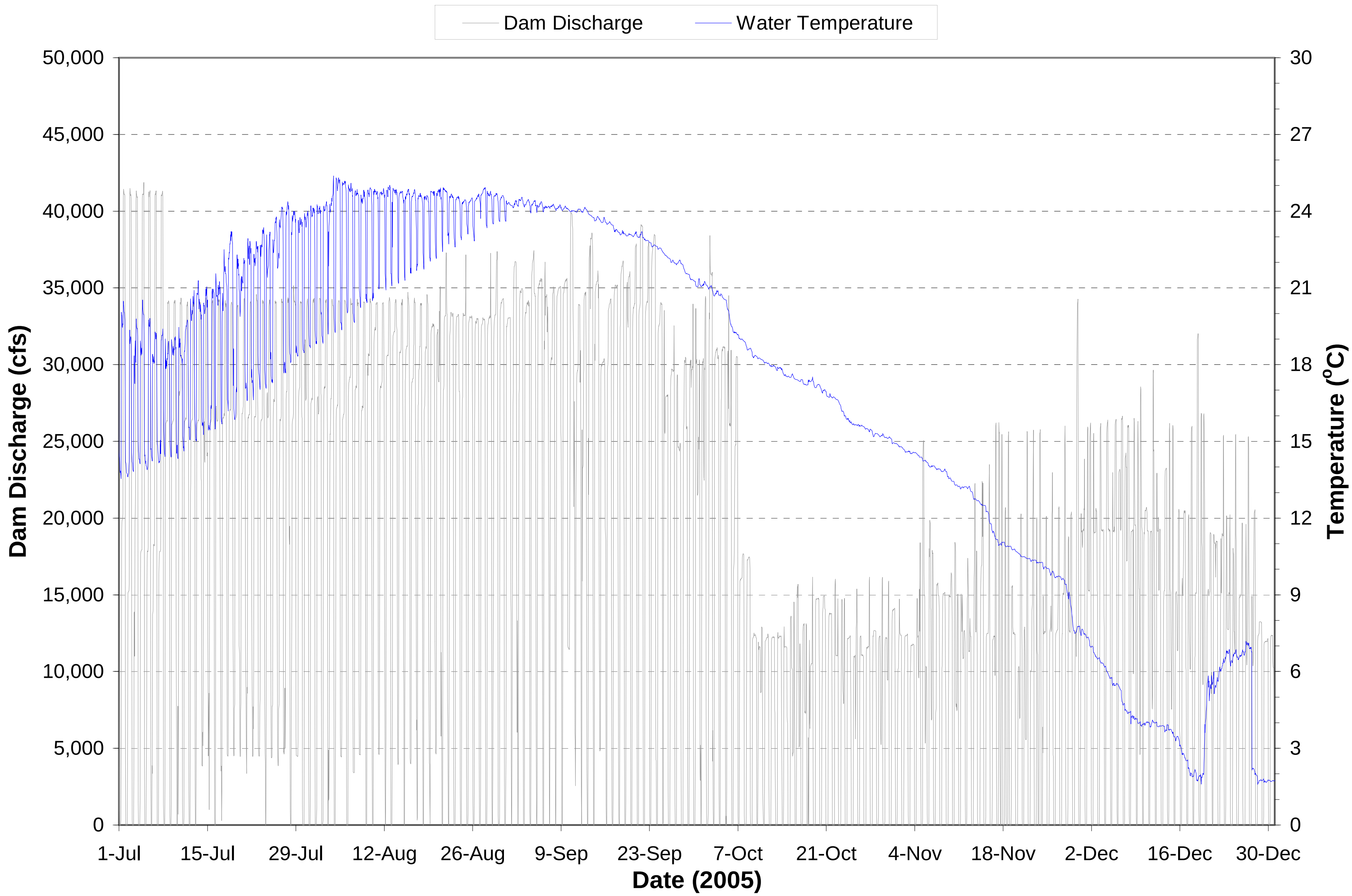


Plate 309. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2005.

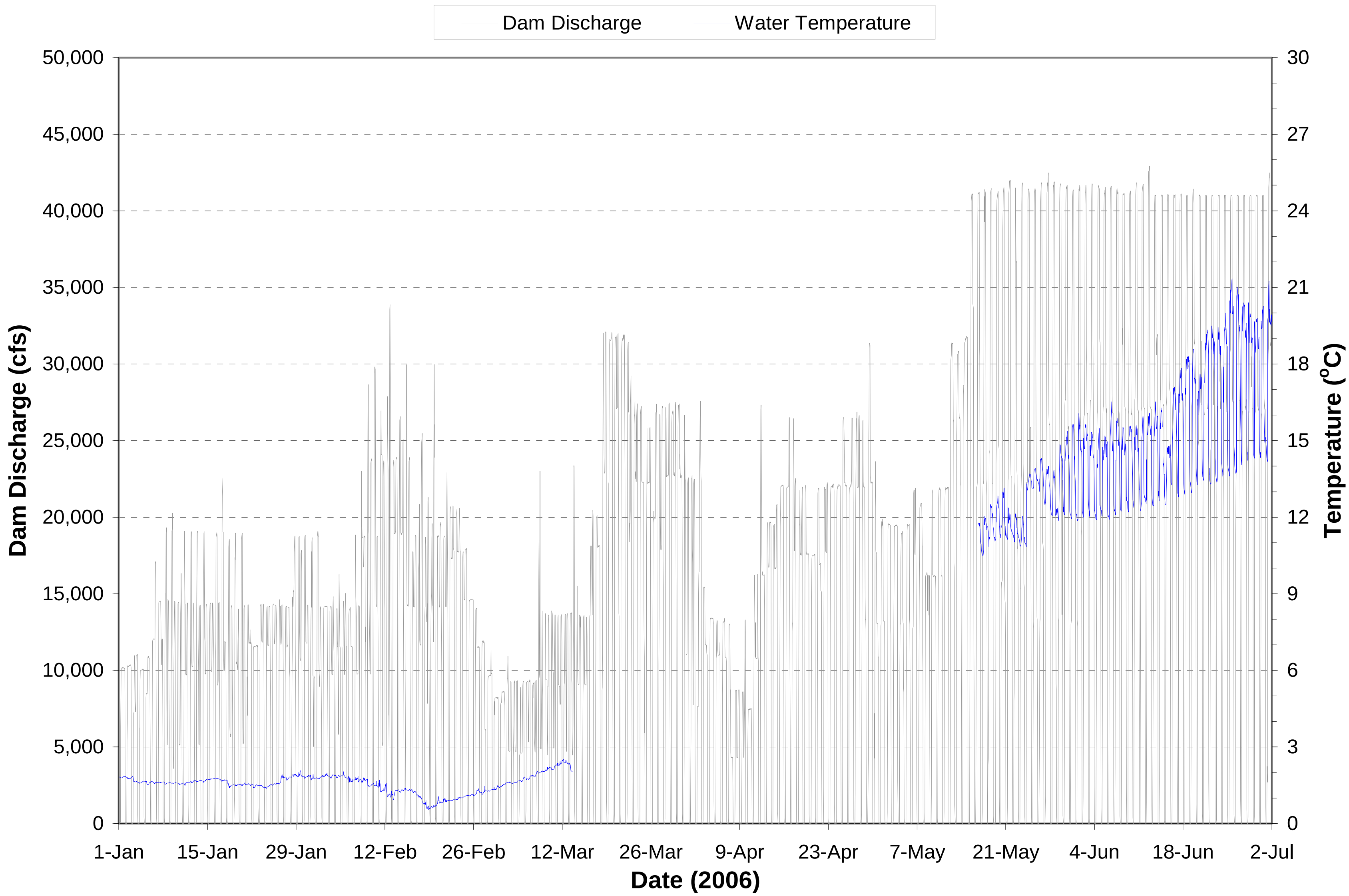


Plate 310. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

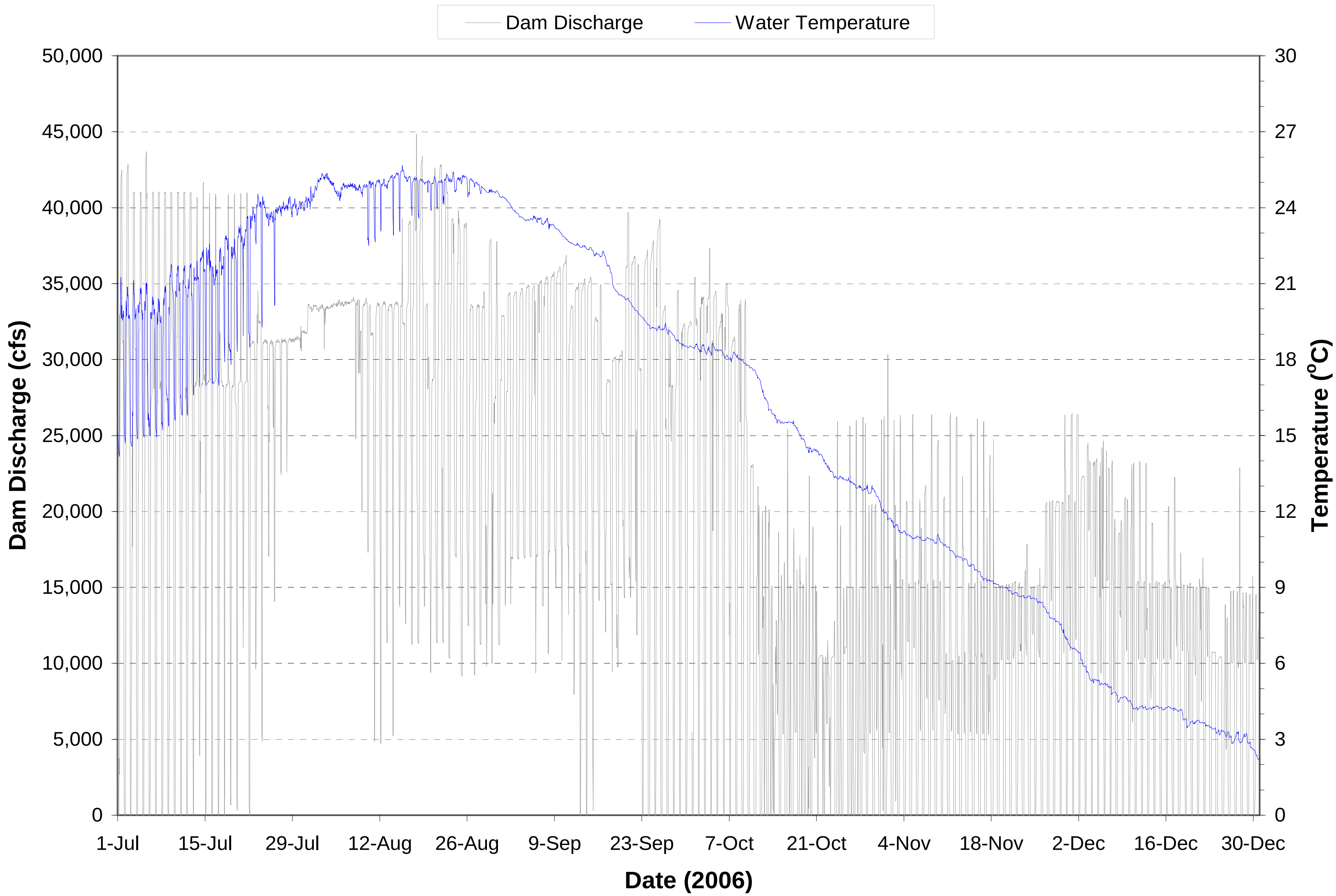


Plate 311. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2006.

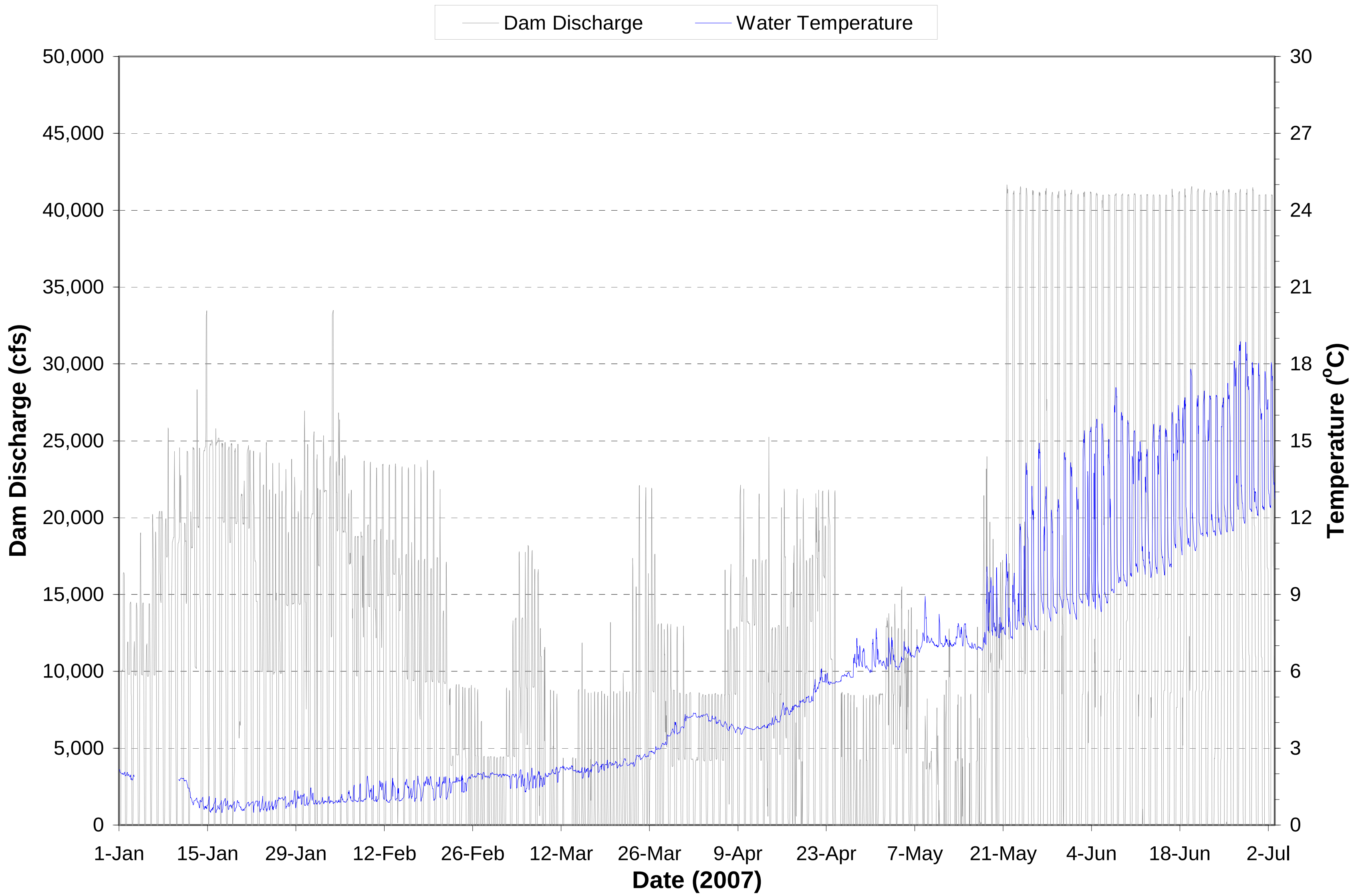


Plate 312. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2007.

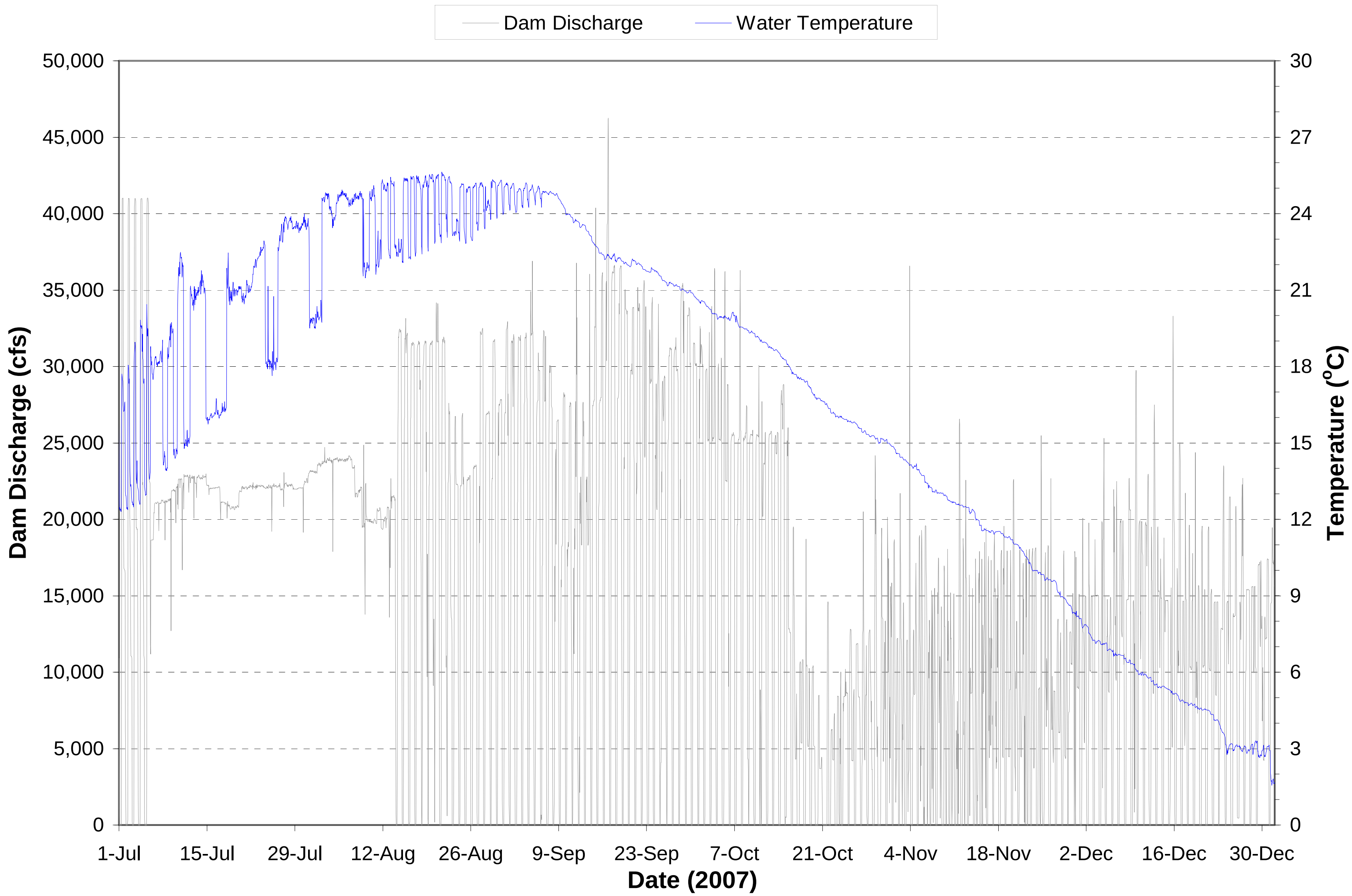


Plate 313. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2007.

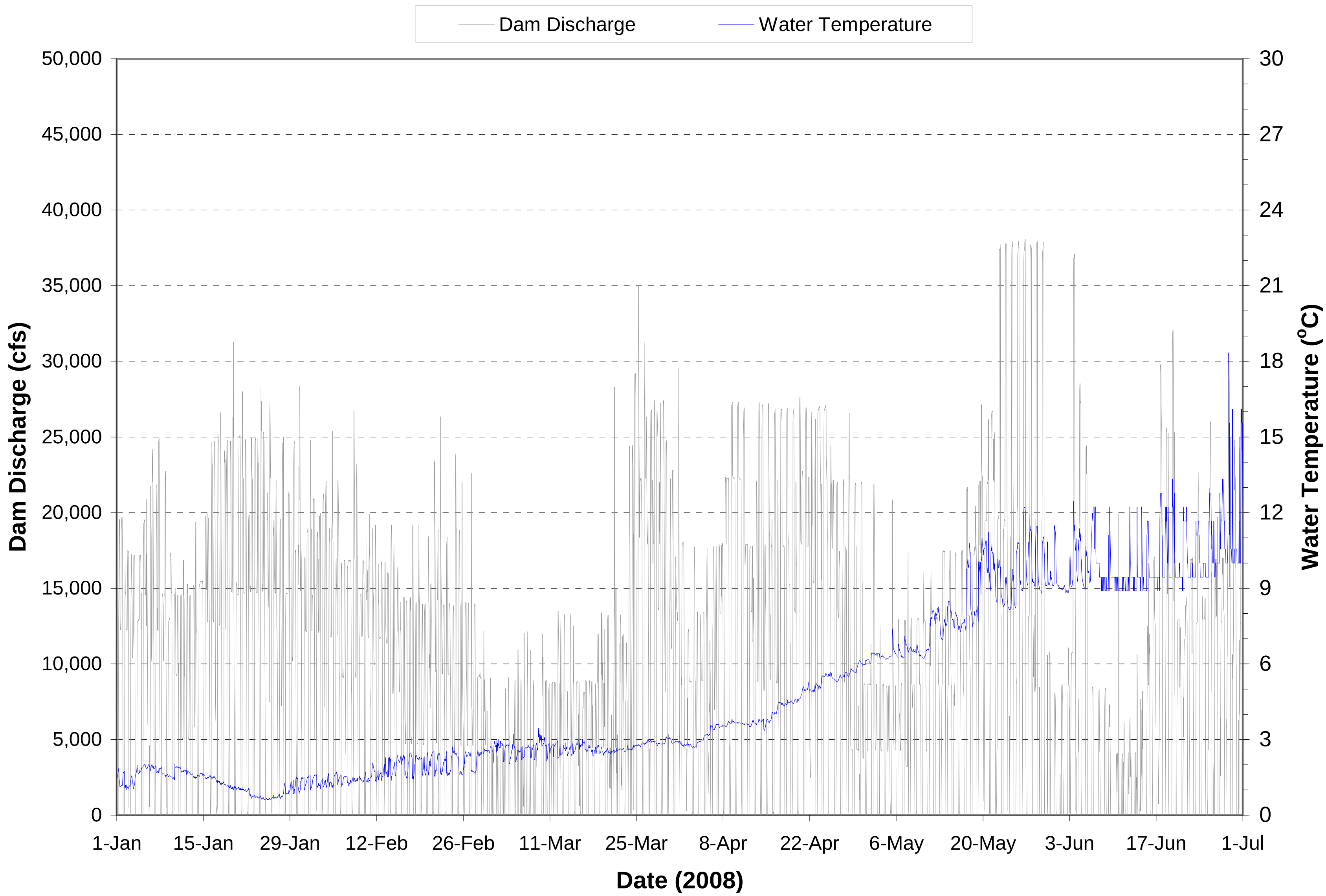


Plate 314. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2008.

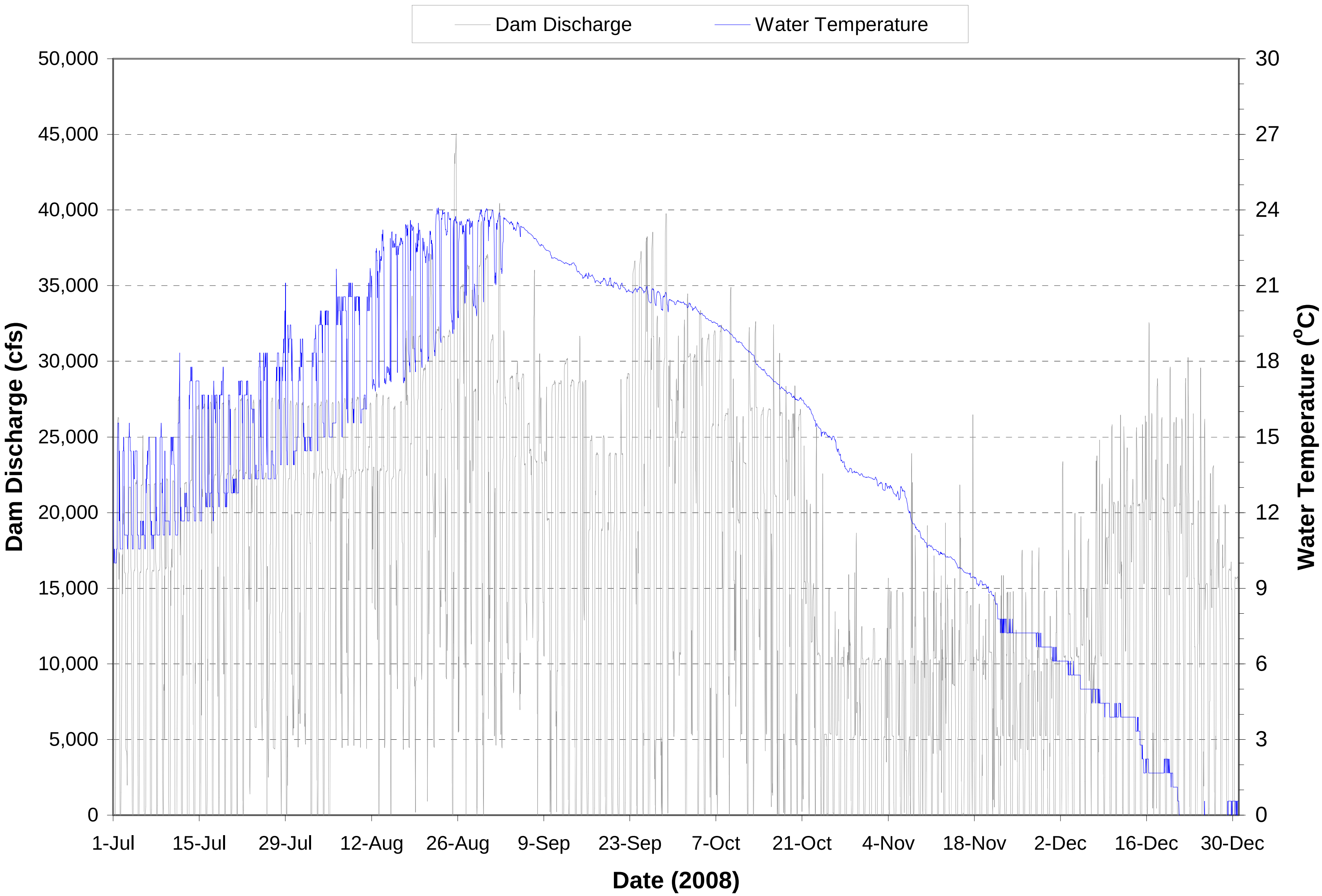


Plate 315. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2008.

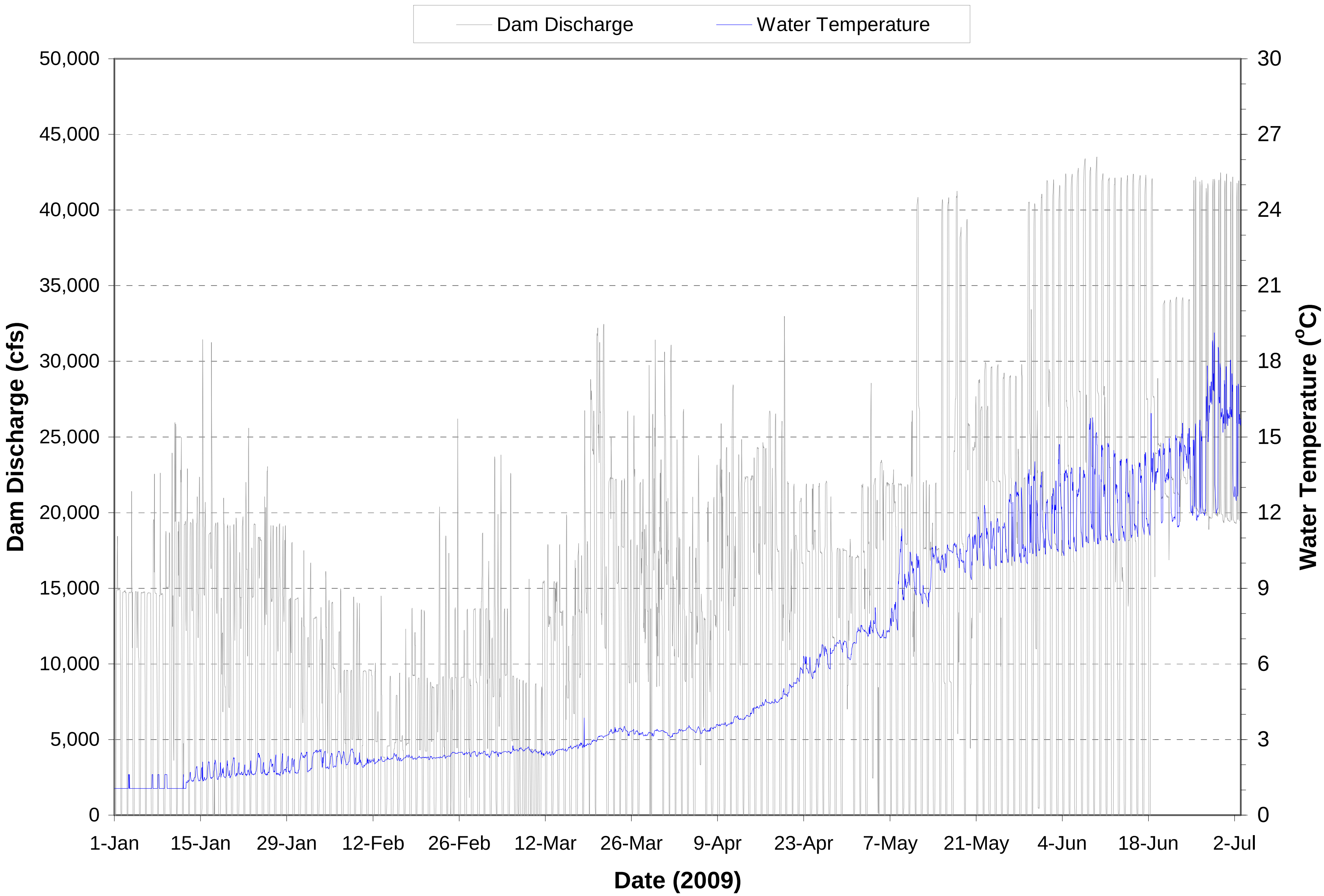


Plate 316. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2009.

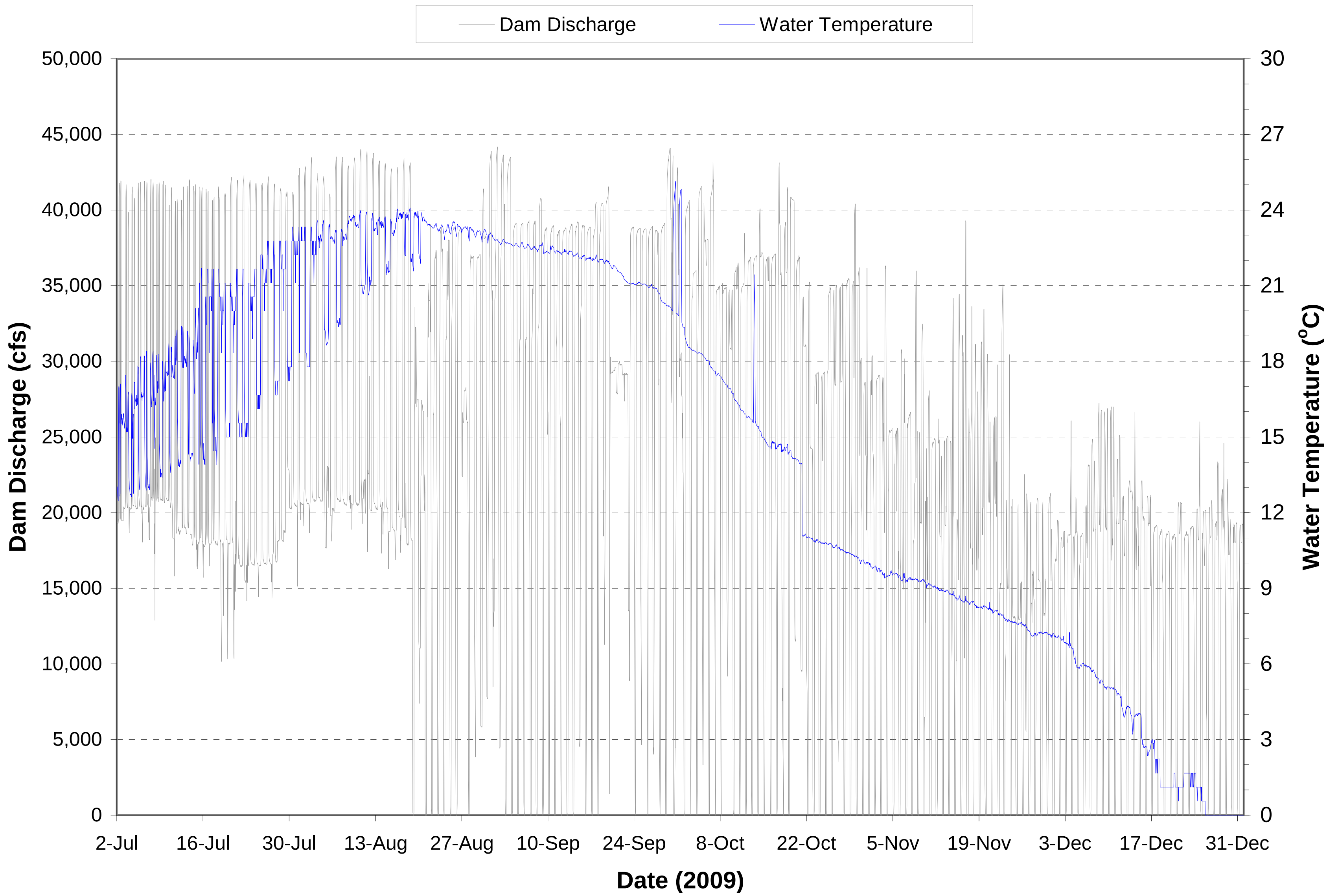


Plate 317. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2009.

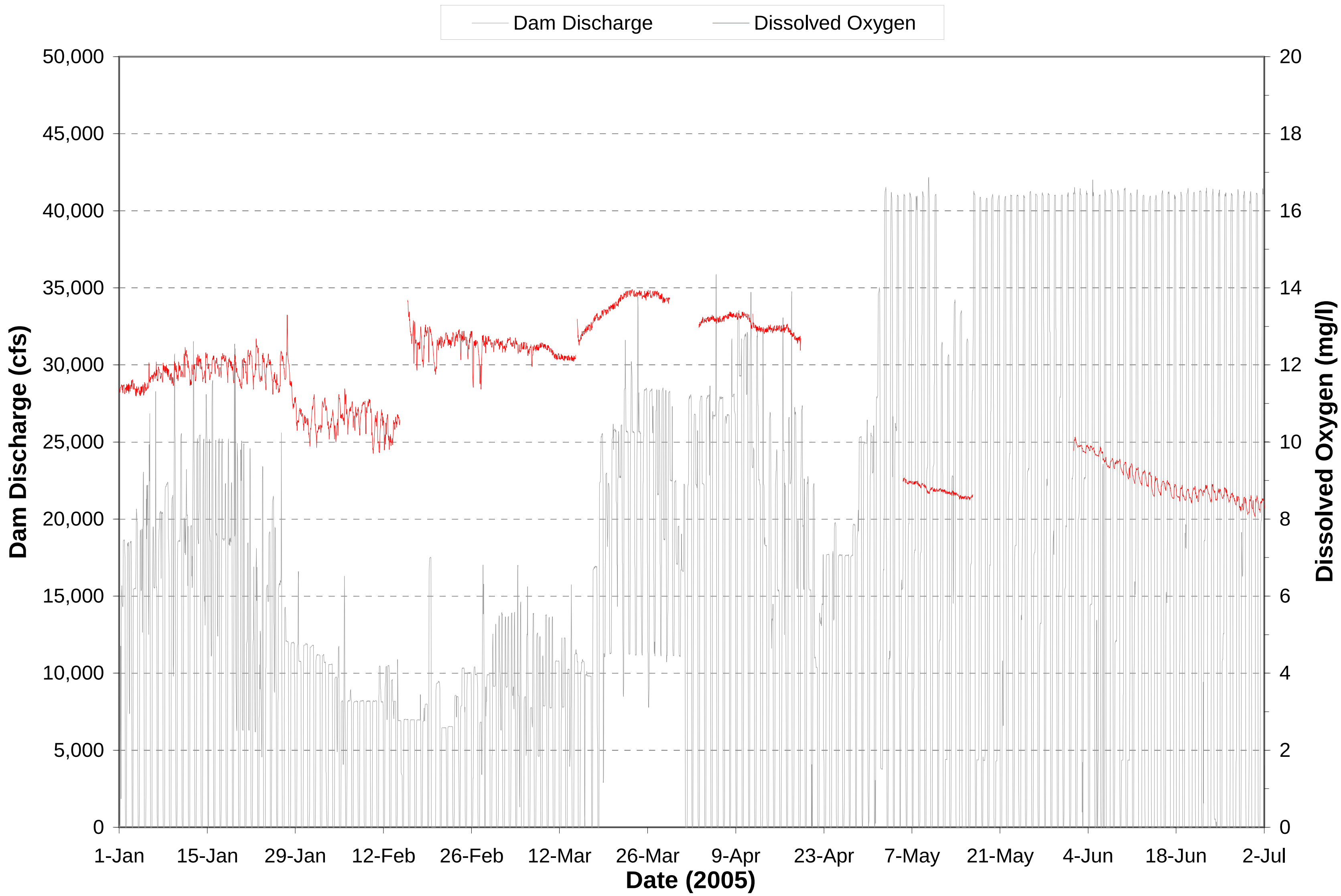


Plate 318. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2005.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

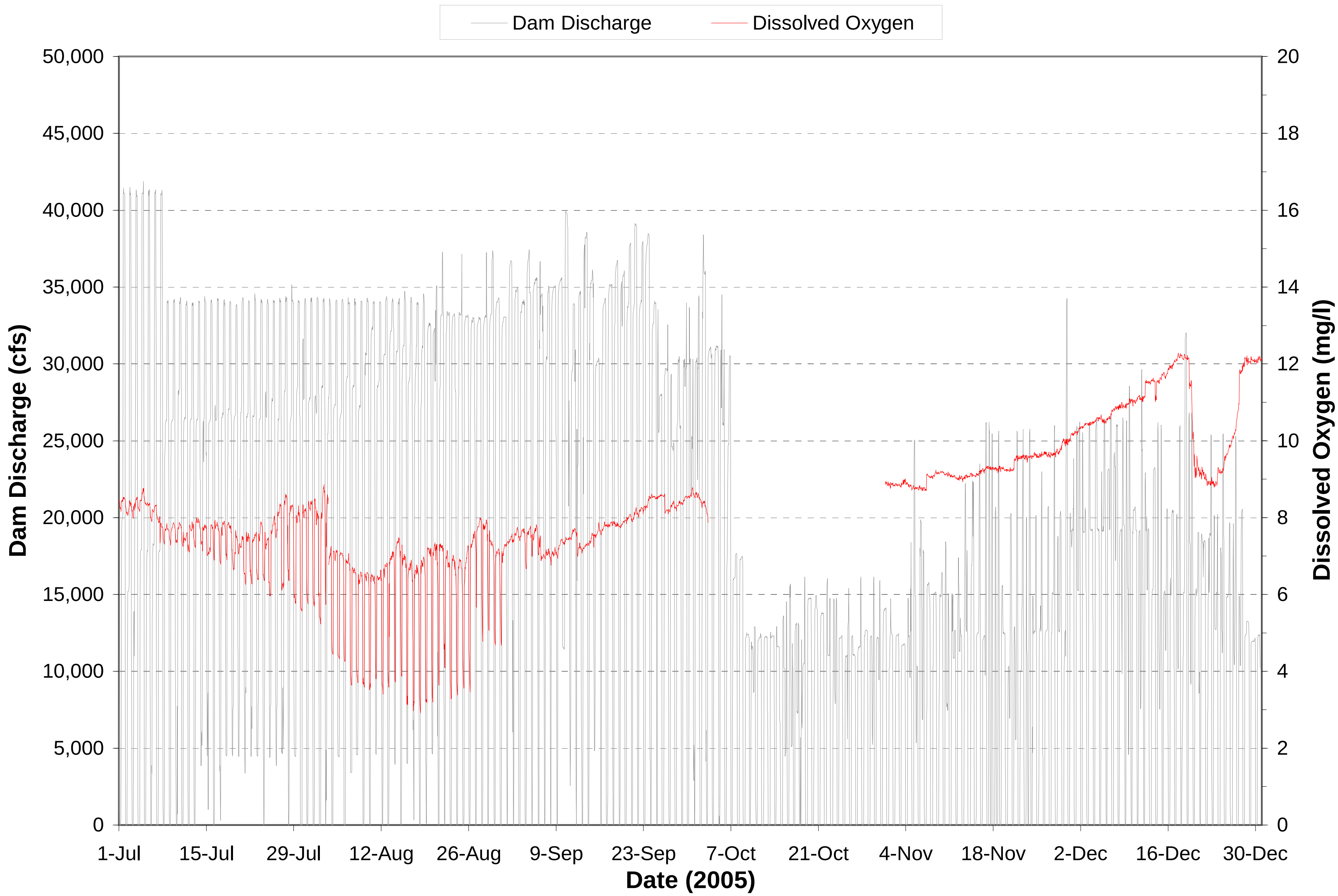


Plate 319. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2005.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

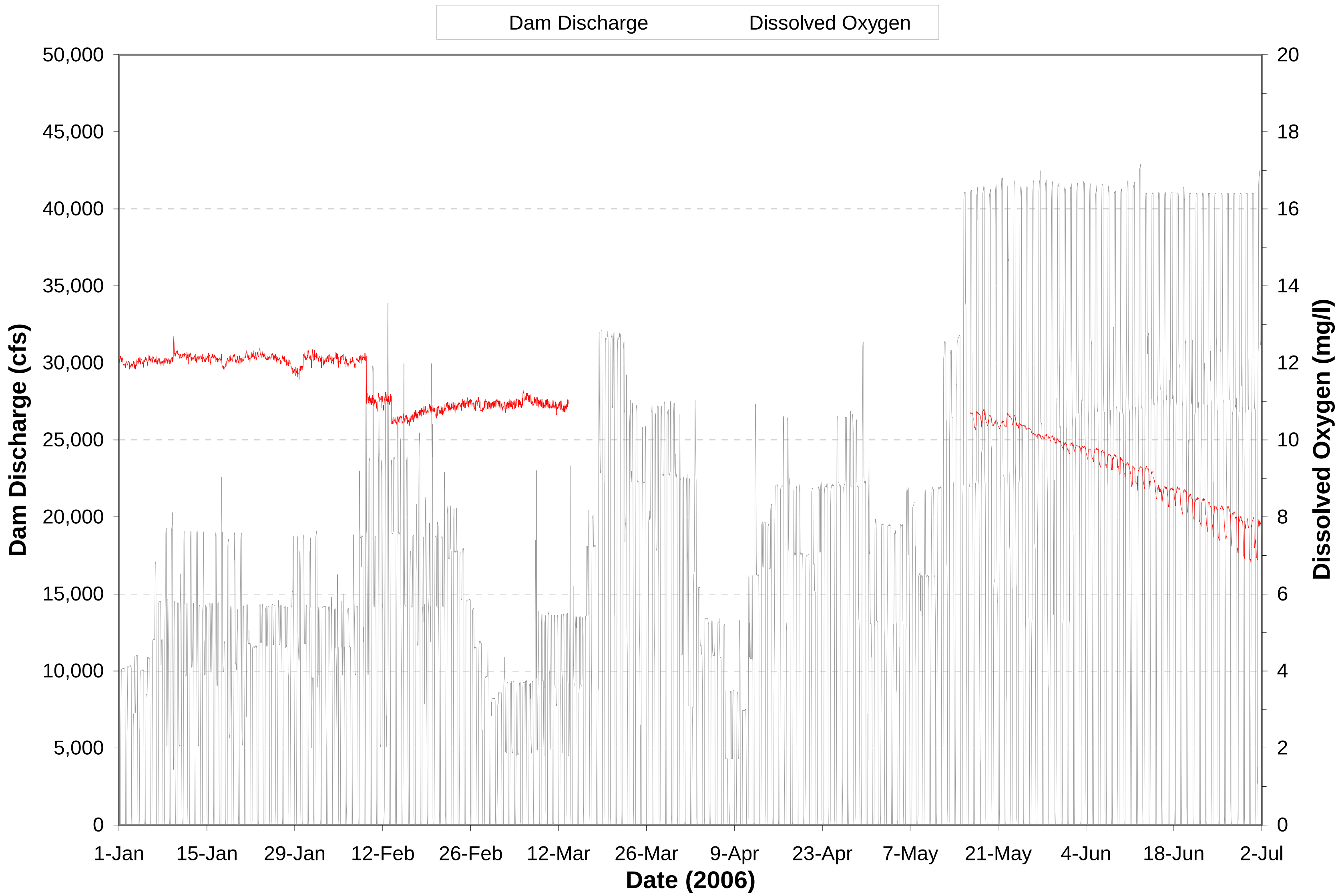


Plate 320. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

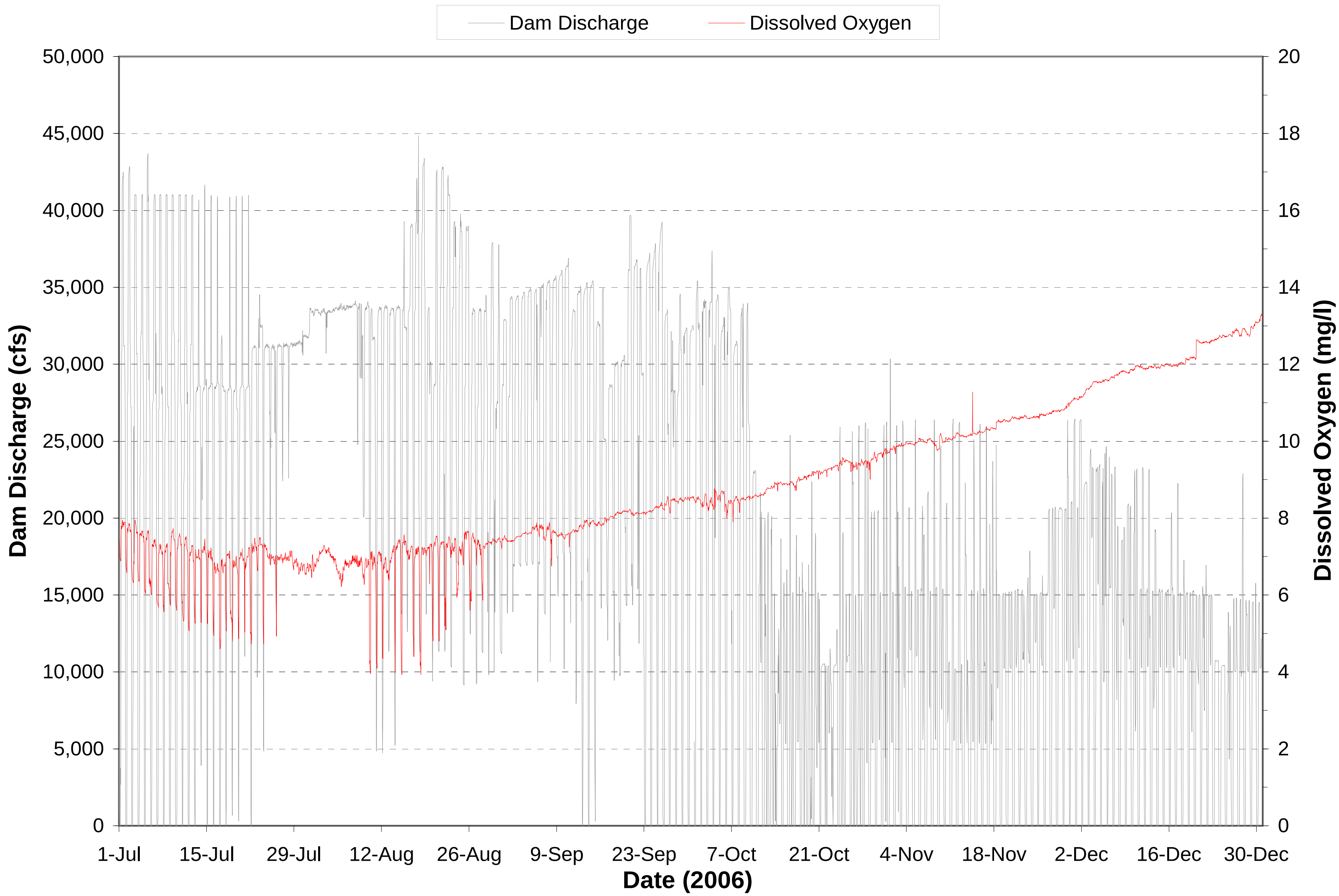


Plate 321. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2006.

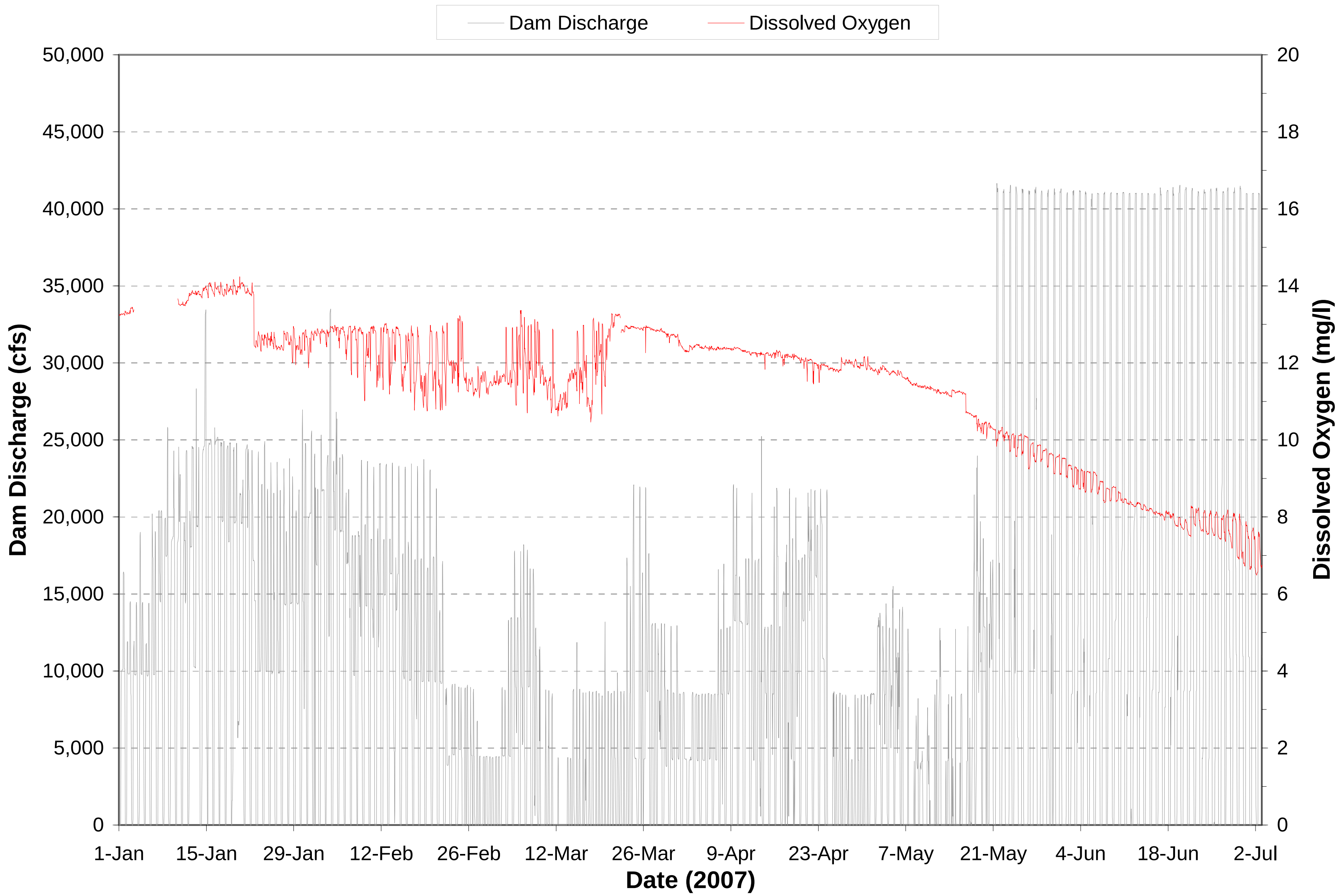


Plate 322. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2007.

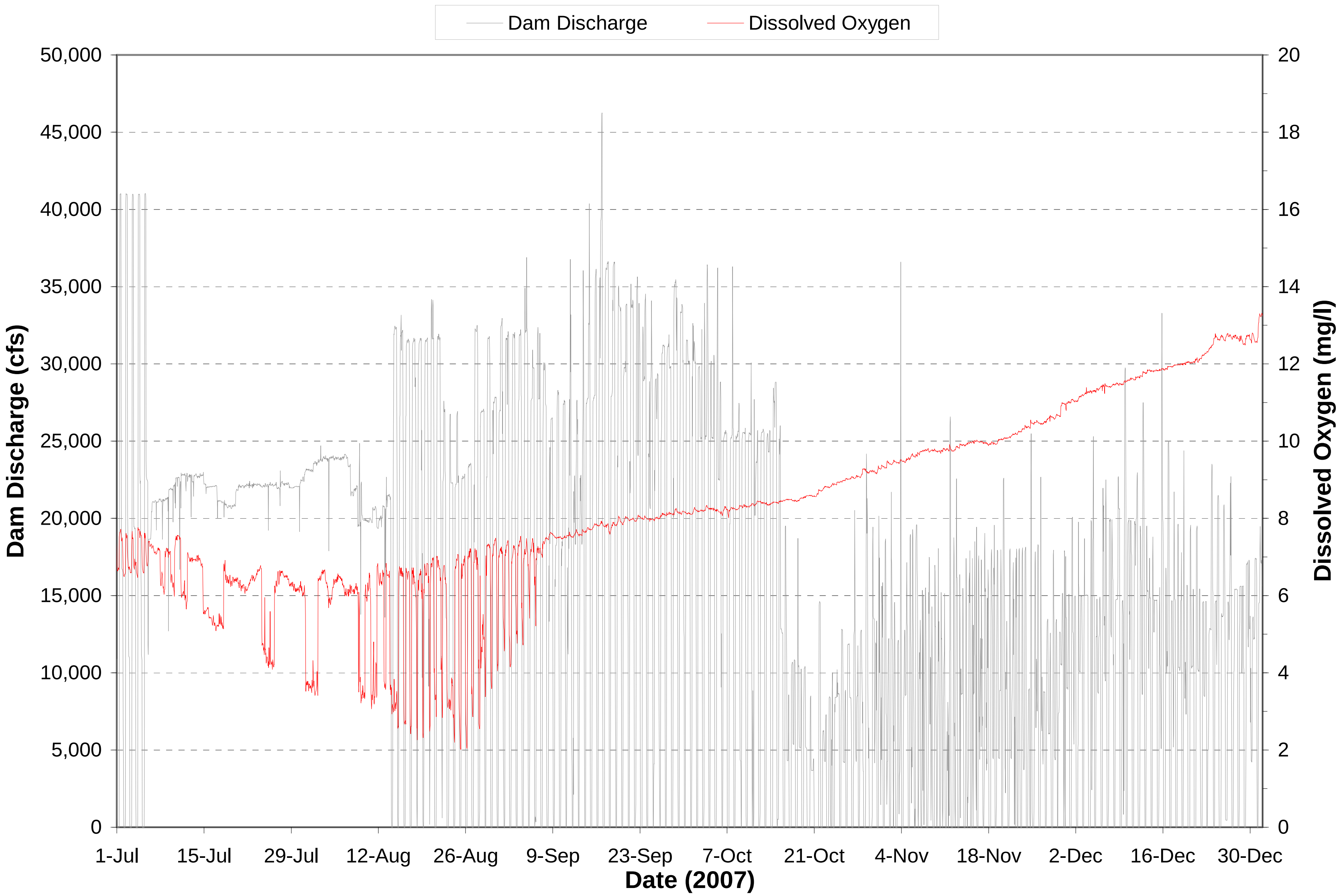


Plate 323. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2007.

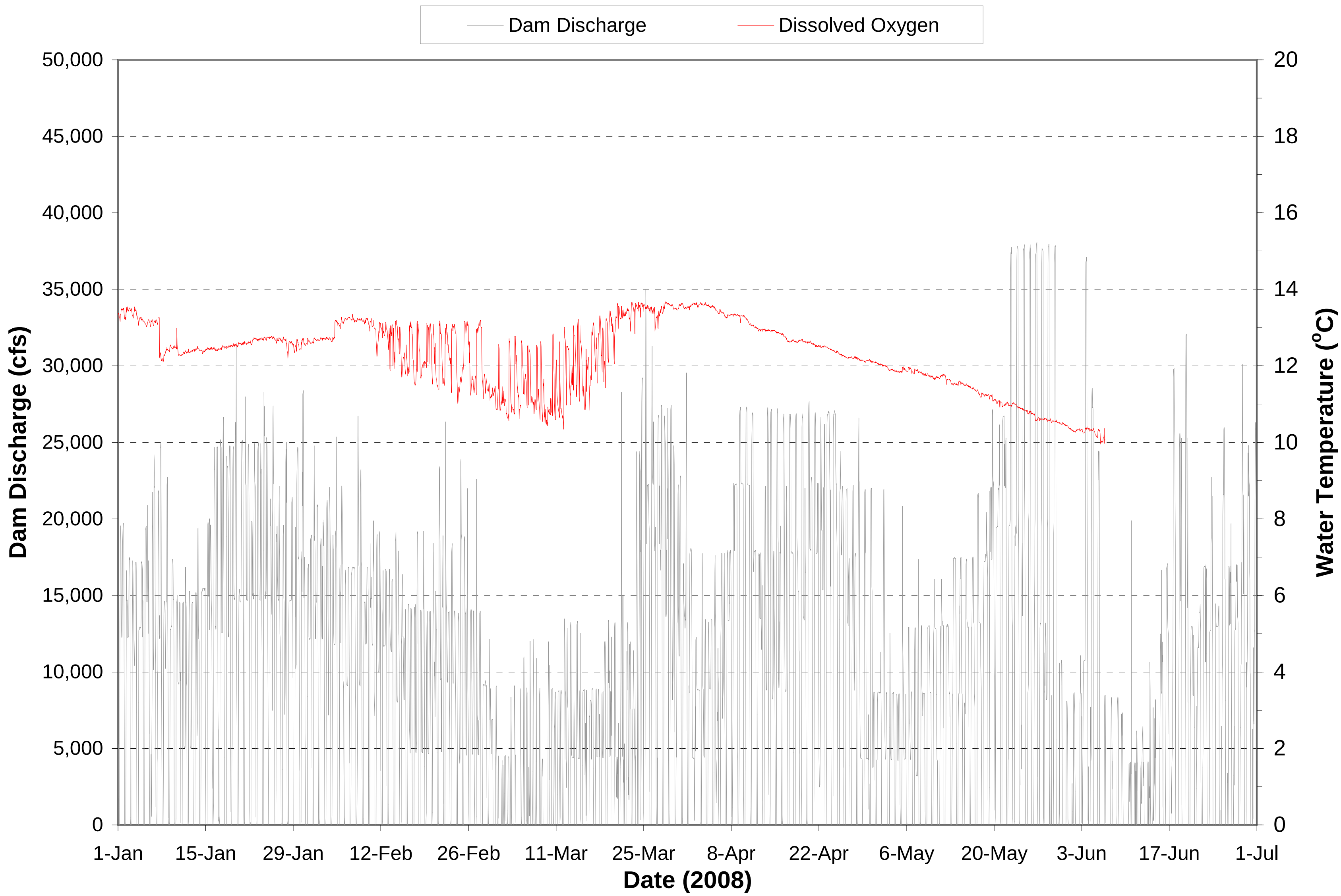


Plate 324. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2008.
(Note: The dissolved oxygen monitoring probe malfunctioned in June and no measurements were collected through the end of 2008.)

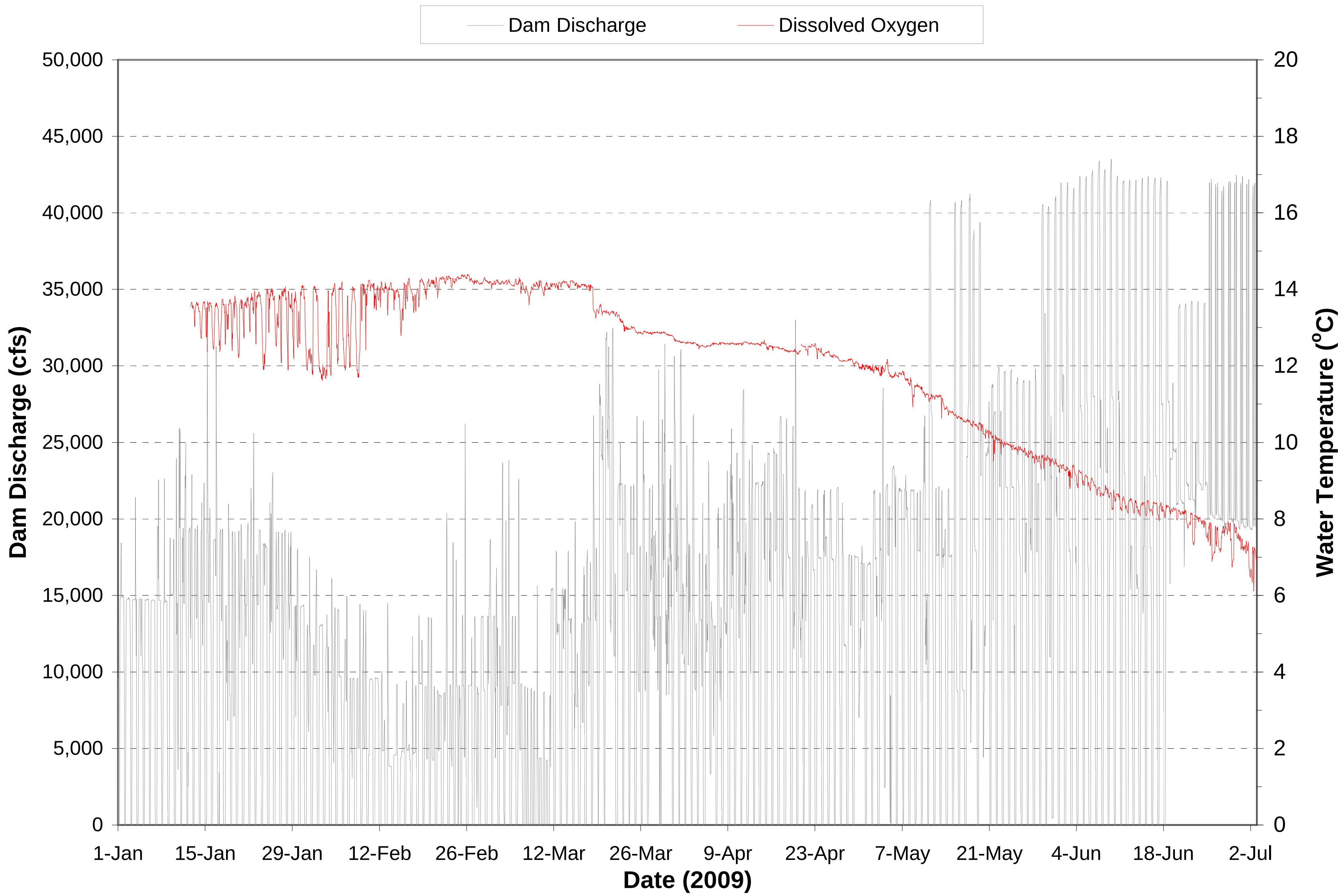


Plate 325. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2009.
(Note: The dissolved oxygen monitoring probe malfunctioned in June and no measurements were collected through the end of 2008.)

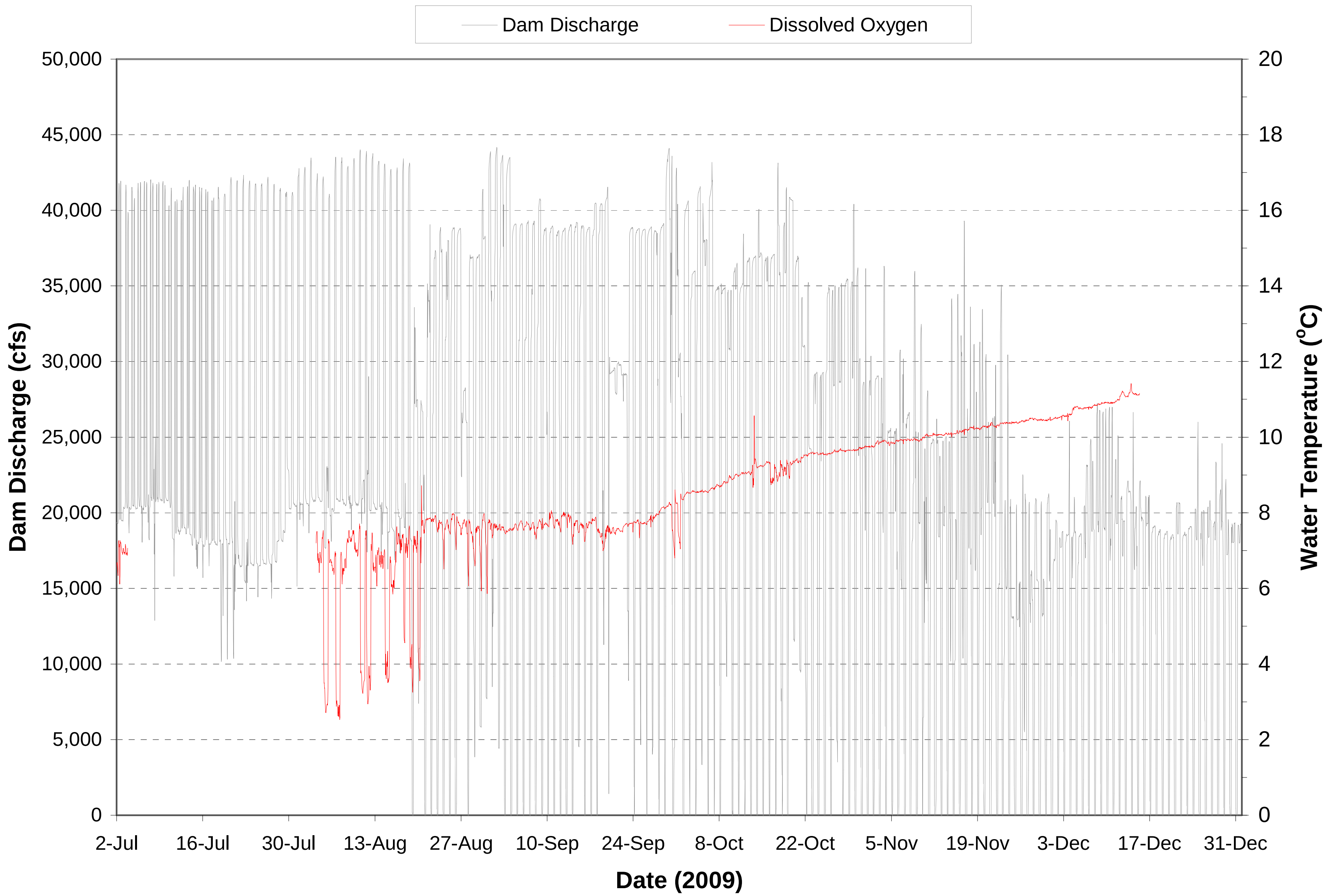


Plate 326. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2009.
(Note: The dissolved oxygen monitoring probe malfunctioned in June and no measurements were collected through the end of 2008.)

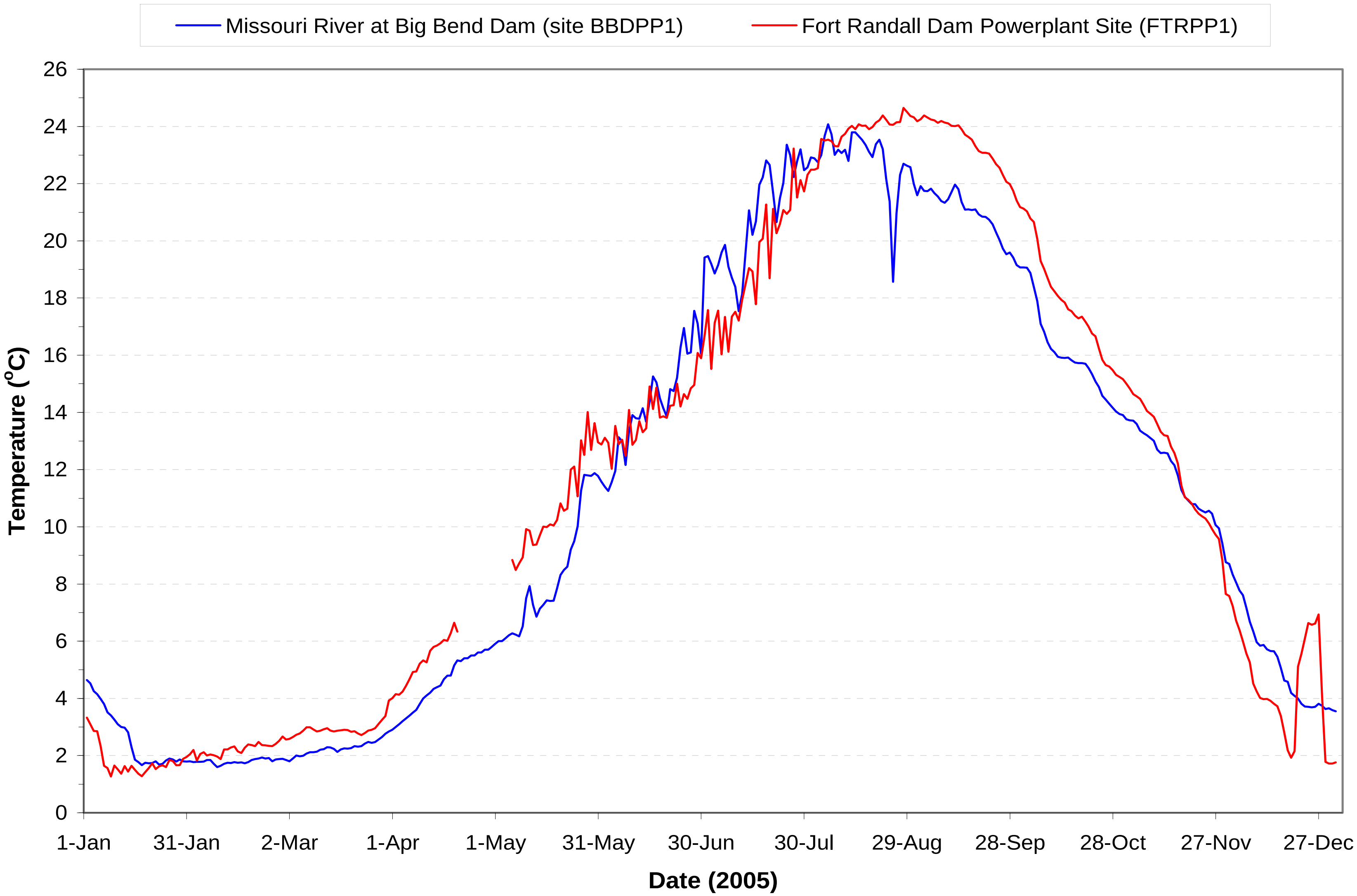


Plate 327. Mean daily water temperatures monitored at the Fort Randall Powerplant (i.e., site FTRPP1) and the Missouri River at Big Bend Dam (i.e., site BBDPP1) during 2005.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

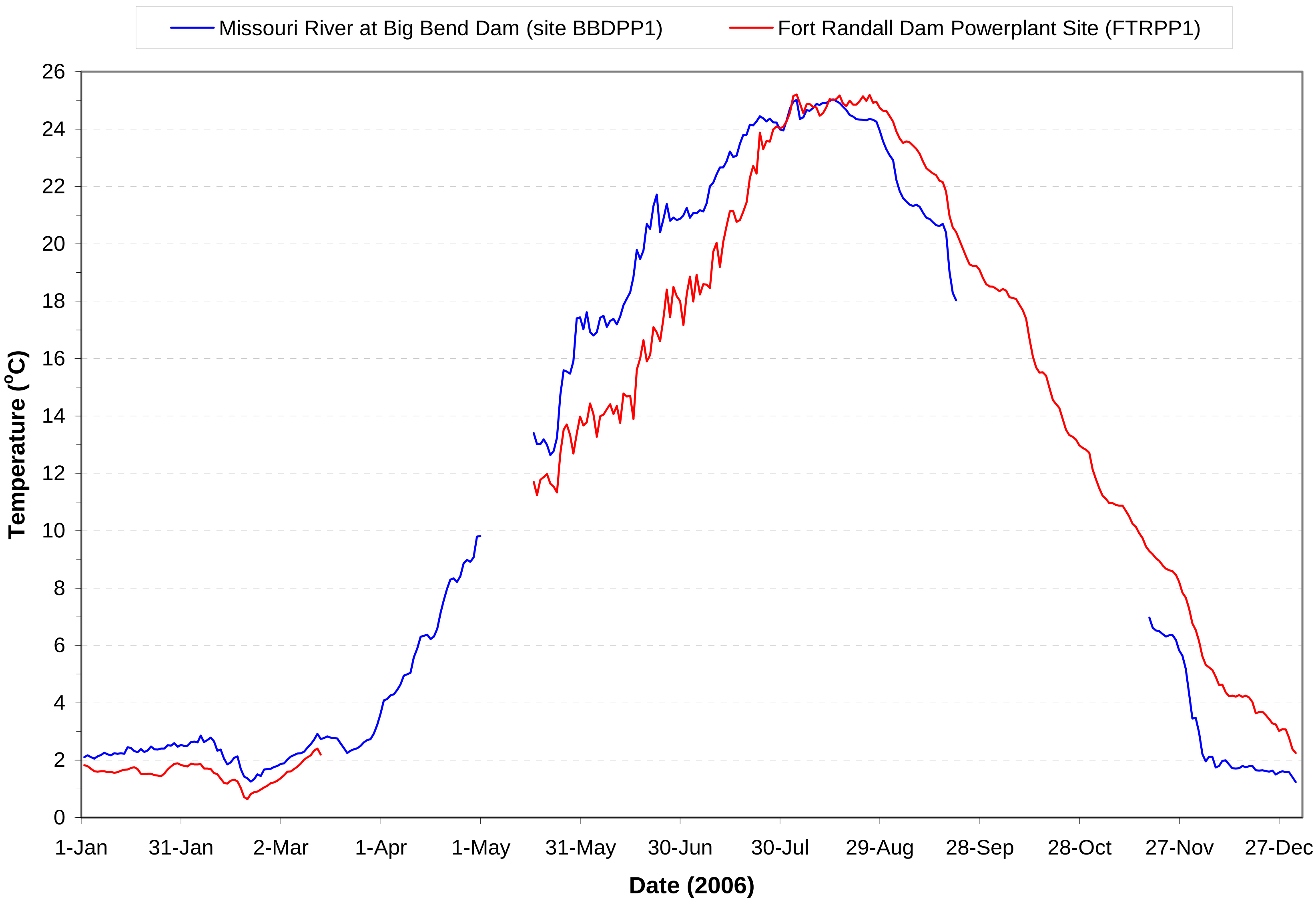


Plate 328. Mean daily water temperatures monitored at the Fort Randall Powerplant (i.e., site FTRPP1) and the Missouri River at Big Bend Dam (i.e., site BBDPP1) during 2006.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

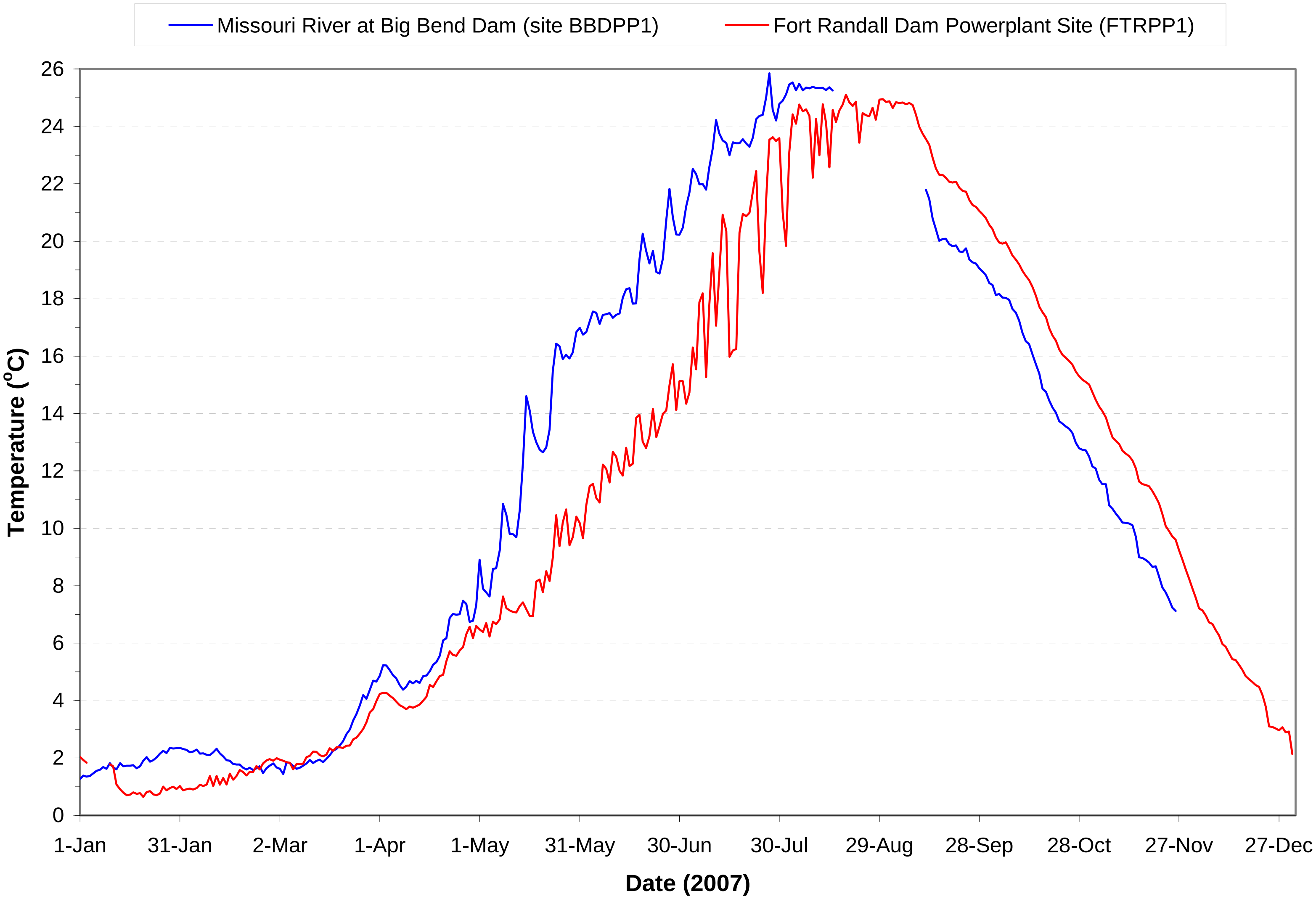


Plate 329. Mean daily water temperatures monitored at the Fort Randall Powerplant (i.e., site FTRPP1) and the Missouri River at Big Bend Dam (i.e., site BBDPP1) during 2007.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.).

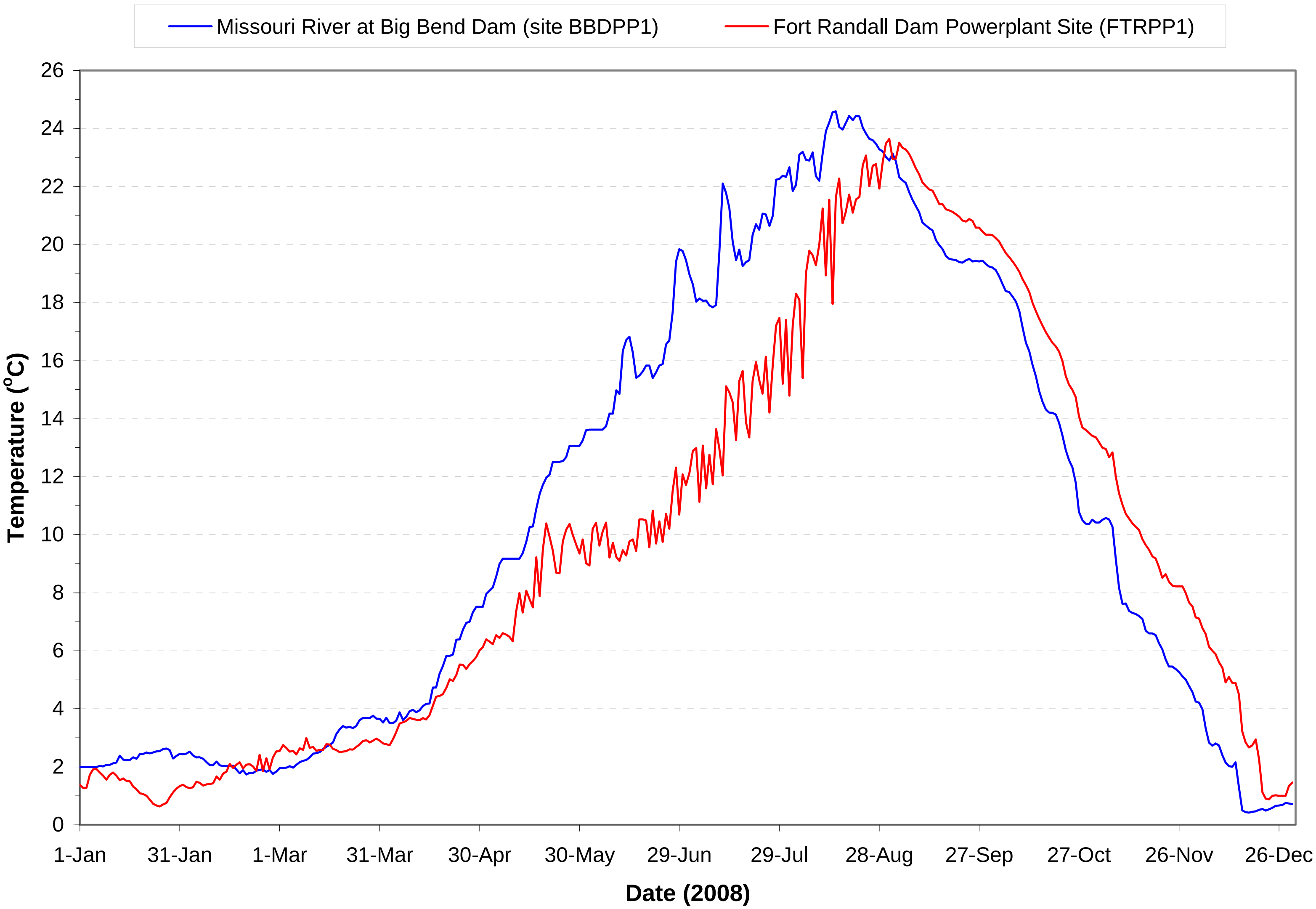


Plate 330. Mean daily water temperatures monitored at the Fort Randall Powerplant (i.e., site FTRPP1) and the Missouri River at Big Bend Dam (i.e., site BBDPP1) during 2008.

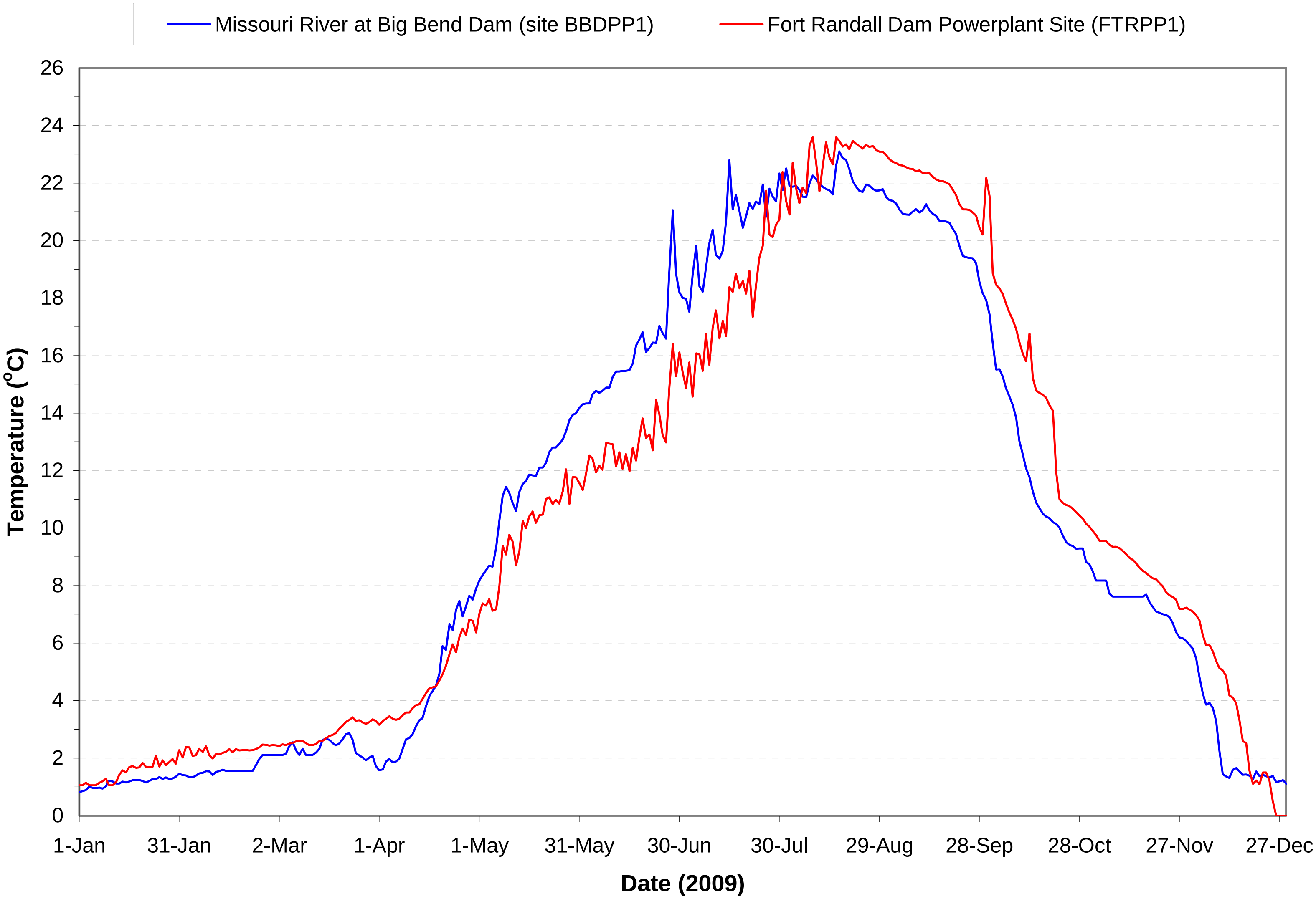


Plate 331. Mean daily water temperatures monitored at the Fort Randall Powerplant (i.e., site FTRPP1) and the Missouri River at Big Bend Dam (i.e., site BBDPP1) during 2009.

Plate 332. Summary of water quality conditions monitored in the Missouri River at the Fort Randall Dam tailwaters (i.e., site FTRRRTW1) during the 5-year period of 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	77	19,339	18,500	0	42,400	-----	-----	-----
Water Temperature (°C)	0.1	78	12.5	12.6	0.7	26.2	27[1,4]	0	0%
Dissolved Oxygen (mg/l)	0.1	77	10.2	10.4	4.9	16.9	≥ 5[1,5]	1	1%
Dissolved Oxygen (% Sat.)	0.1	77	95.1	97.7	57.6	117.4	-----	-----	-----
pH (S.U.)	0.1	76	8.2	8.3	6.8	8.7	6.5[1,2,5], 9.0[1,2,4], 9.5[3,4]	0	0%
Specific Conductance (umho/cm)	1	77	700	719	535	821	-----	-----	-----
Oxidation-Reduction Potential	1	36	381	369	305	516	-----	-----	-----
Alkalinity, Total (mg/l)	7	80	167	167	130	209	-----	-----	-----
Carbon, Dissolved Organic (mg/l)	0.05	8	3.1	3.1	2.4	3.6	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	76	3.4	3.2	1.6	16.1	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	80	10	10	n.d.	53	-----	-----	-----
Chloride (mg/l)	1	80	12	12	5	31	438[2,4], 250[2,6]	0	0%
Color (S.U. - APHA)	1	8	5	6	n.d.	11	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	59	499	480	440	840	1,750[2,4], 1,000[2,7], 3,500[3,4], 2,000[3,6]	0	0%
Hardness, Total (mg/l)	1	15	224	223	186	251	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	80	-----	0.03	n.d.	0.58	5.7 [1,4,7], 1.7 [1,6,7]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	80	0.5	0.4	n.d.	3.2	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	79	-----	n.d.	n.d.	1.40	10[2,4]	0	0%
Nitrogen, Total (mg/l)	0.1	79	0.6	0.4	n.d.	4.1	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	7	-----	n.d.	n.d.	0.02	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	80	-----	0.03	n.d.	0.73	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	18	-----	n.d.	n.d.	0.03			
Suspended Solids, Total (mg/l)	4	80	-----	n.d.	n.d.	178	158[1,4], 90[1,6]	1, 1	1%, 1%
Turbidity (NTU)	1	77	11	7	n.d.	67	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	10	-----	n.d.	n.d.	50	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	1.5	5.6[10]	0	0%
Arsenic, Dissolved (ug/l)	1	11	1	1	n.d.	3	340[8], 150[9], 0.018[10]	b.d.	b.d.
Barium, Dissolved (ug/l)	5	11	37	37	31	44	-----	-----	-----
Beryllium, Dissolved (ug/l)	2	12	-----	n.d.	n.d.	n.d.	4[10]	0	0%
Cadmium, Dissolved (ug/l)	0.2	11	-----	n.d.	n.d.	n.d.	4.4[8], 0.4[9], 5[10]	0	0%
Chromium, Dissolved (ug/l)	10	20	-----	n.d.	n.d.	n.d.	1,099[8], 143[9]	0	0%
Copper, Dissolved (ug/l)	2	18	-----	n.d.	n.d.	3	29[8], 18[9], 1,300[10]	0	0%
Iron, Dissolved (ug/l)	7	10	-----	n.d.	n.d.	152	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	0.8	153[8], 6.0[9]	0	0%
Manganese, Dissolved (ug/l)	21	10	-----	n.d.	n.d.	22			
Mercury, Dissolved (ug/l)	0.05	19	-----	n.d.	n.d.	n.d.	1.7[8], 0.05[9]	0	0%
Mercury, Total (ug/l)	0.05	19	-----	n.d.	n.d.	n.d.	0.77[9]	0	0%
Nickel, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	923[8], 103[9], 610[10]	0	0%
Selenium, Total (ug/l)	1	12	-----	3	n.d.	4	-----	-----	-----
Silver, Dissolved (ug/l)	1	18	-----	n.d.	n.d.	n.d.	12.8[8]	0	0%
Zinc, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	20	231[8,9], 7,400[10]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	19	-----	n.d.	n.d.	n.d.			
Alachlor, Total (ug/l)[D]	0.05	47	-----	n.d.	n.d.	n.d.	-----	-----	-----
Atrazine, Total (ug/l)[D]	0.05	66	-----	n.d.	n.d.	0.11	-----	-----	-----
Metolachlor, Total (ug/l)[D]	0.05	66	-----	n.d.	n.d.	0.30	-----	-----	-----
Pesticide Scan (ug/l)[E]	0.05	12	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

[A] Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for the protection of warmwater permanent fish life propagation waters.
- [2] Criteria for the protection of domestic water supply waters.
- [3] Criteria for the protection of commerce and industry waters.
- [4] Daily maximum criterion (monitoring results directly comparable to criterion).
- [5] Daily minimum criterion (monitoring results directly comparable to criterion).
- [6] 30-day average criterion (monitoring results not directly comparable to criterion).
- [7] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- [8] Acute (CMC) criterion for the protection of freshwater aquatic life.
- [9] Chronic (CCC) criterion for the protection of freshwater aquatic life.
- [10] Criterion for the protection of human health.

Note: Some of South Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] Immunoassay analysis.

[E] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

Plate 333. Summary of water quality conditions monitored in the Missouri River near Verdel, Nebraska (i.e., site MORRR0851) at RM851 during the 5-year period of 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	71	21,759	21,889	3,012	41,898	-----	-----	-----
Water Temperature (°C)	0.1	70	14.2	14.5	0.5	26.3	27[1,2,6], 29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0.1	69	9.9	9.5	6.4	13.7	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	69	97.0	98.1	73.3	118.8	-----	-----	-----
pH (S.U.)	0.1	69	8.3	8.3	7.6	8.7	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Specific Conductance (umho/cm)	1	70	697	721	432	814	2,000[4]	0	0%
Oxidation-Reduction Potential	1	32	376	364	299	486	-----	-----	-----
Alkalinity, Total (mg/l)	7	71	165	165	118	220	-----	0	0%
Carbon, Total Dissolved (mg/l)	0.05	8	2.8	3.0	1.2	3.6	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	69	3.4	3.0	1.6	12.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	71	10	9	n.d.	47	-----	-----	-----
Chloride (mg/l)	1	70	12	12	5	31	438[3,6], 250[3,8]	0	0%
Chlorophyll *a* (ug/l)	1	7	5	4	n.d.	13			
Color (S.U. - APHA)	1	8	6	6	n.d.	13	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	52	495	485	310	780	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	9[6]	27%[6]
Hardness, Total (mg/l)	1	13	223	222	167	245	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	71	-----	0.03	n.d.	0.41	4.7 [1,6,9], 1.4 [1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	71	0.5	0.4	n.d.	3.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	71	-----	n.d.	n.d.	0.50	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	71	0.5	0.4	n.d.	3.9	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	11	-----	n.d.	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	71	0.05	0.02	n.d.	0.75	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	22	-----	n.d.	n.d.	0.02	-----	-----	-----
Suspended Solids, Total (mg/l)	4	71	-----	6	n.d.	230	158[1,6], 90[1,8]	1, 1	1%, 1%
Turbidity (NTU)	1	67	15	10	n.d.	129	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	8	-----	n.d.	n.d.	n.d.	750[10], 87[11], 200[12]	0	0%
Antimony, Dissolved (ug/l)	0.5	9	-----	n.d.	n.d.	2.0	88[10], 30[11], 6[12]	0	0%
Arsenic, Dissolved (ug/l)	1	10	2	2	1	4	340[10], 16.7[11], 10[12]	0	0%
Barium, Dissolved (ug/l)	5	9	38	37	33	43	2,000[11]	0	0%
Beryllium, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	n.d.	130[10], 5.3[11], 4[12]	0	0%
Cadmium, Dissolved (ug/l)	0.2	8	-----	n.d.	n.d.	1.0	4.4[10], 0.43[11], 5[12]	0, 1, 0	0%, 13%, 0%
Chromium, Dissolved (ug/l)	10	16	-----	n.d.	n.d.	n.d.	1,095[10], 142[11], 100[12]	0	0%
Copper, Dissolved (ug/l)	2	15	-----	n.d.	n.d.	3	28[10], 18[11], 1,000[12]	0	0%
Iron, Dissolved (ug/l)	7	12	-----	n.d.	n.d.	100	1,000[11]	0	0%
Lead, Dissolved (ug/l)	0.5	9	-----	n.d.	n.d.	0.8	152[10], 5.9[11], 15[12]	0	0%
Manganese, Dissolved (ug/l)	2	12	-----	n.d.	n.d.	40	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	16	-----	n.d.	n.d.	n.d.	1.4[10]	0	0%
Mercury, Total (ug/l)	0.05	16	-----	n.d.	n.d.	n.d.	0.77[11], 2[12]	0	0%
Nickel, Dissolved (ug/l)	10	16	-----	n.d.	n.d.	10	919[10], 102[11], 100[12]	0	0%
Selenium, Total (ug/l)	1	9	2	2	1	4	20[4,10], 5[11], 50[12]	0	0%
Silver, Dissolved (ug/l)	1	16	-----	n.d.	n.d.	n.d.	14[10], 100[12]	0	0%
Thallium, Dissolved (ug/l)	0.5	9	-----	n.d.	n.d.	n.d.	1,400[10], 6.3[11], 2[12]	0	0%
Zinc, Dissolved (ug/l)	5	16	-----	n.d.	n.d.	n.d.	230[10,11], 5,000[12]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	16	-----	n.d.	n.d.	0.10.	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	44	-----	n.d.	n.d.	n.d.	760[10], 76[11], 2[12]	0	0%
Atrazine, Total (ug/l)[D]	0.05	60	-----	n.d.	n.d.	0.27	330[10], 12[11], 3[12]	0	0%
Metolachlor, Total (ug/l)[D]	0.05	60	-----	n.d.	n.d.	0.20	390[10], 100[11]	0	0%
Pesticide Scan (ug/l)[E]	0.05	11	-----	n.d.	n.d.	n.d.	-----	-----	-----
THM Formation Potential, Total	4	8	169	172	154	171	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (11) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (12) Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

Plate 334. Summary of monthly (May through September) water quality conditions monitored in Lewis and Clark Lake near Gavins Point Dam (Site GPTLK0811A) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	25	1206.6	1206.6	1205.5	1207.7	-----	-----	-----
Water Temperature (°C)	0.1	309	21.1	22.0	10.0	27.8	27[1,2,6], 29[1,2,6]	2, 0	1%, 0%
Dissolved Oxygen (mg/l)	0.1	309	8.0	8.3	1.4	13.1	5[1,7]	29	9%
Dissolved Oxygen (% Sat.)	0.1	309	92.8	96.1	16.7	151.5	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	269	8.5	8.4	4.1	13.1	5[1,7]	4	1%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	40	4.9	4.7	1.4	9.6	5[1,7]	25[F]	63%[F]
Specific Conductance (umho/cm)	1	308	690	704	555	761	2,000[4]	0	0%
pH (S.U.)	0.1	297	8.5	8.5	7.8	9.0	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Turbidity (NTUs)	1	309	18	13	1	132	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	309	340	338	266	496	-----	-----	-----
Secchi Depth (in.)	1	25	36	36	18	52	-----	-----	-----
Alkalinity, Total (mg/l)	7	47	158	160	130	170	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	46	3.4	3.3	1.8	6.1	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	42	11	11	n.d.	19	-----	-----	-----
Chloride (mg/l)	1	42	11	11	8	14	438[3,6], 250[3,8]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	165	21*	17	1	69	8[10]	141	85%
Chlorophyll *a* (ug/l) – Lab Determined	1	24	13*	12	n.d.	53	8[10]	16	67%
Color (S.U. - APHA)	1	10	7	7	4	10	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	44	471	463	400	576	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	48	-----	0.04	n.d.	0.24	3.2 [1,6,9], 0.63[1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	48	0.5	0.5	n.d.	1.6	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	48	-----	n.d.	n.d.	0.30	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	48	0.56	0.5	n.d.	1.7	0.57[10]	19	40%
Phosphorus, Dissolved (mg/l)	0.02	38	-----	n.d.	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	48	0.05	0.04	n.d.	0.23	0.06[10]	9	19%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	48	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	44	201	202	177	223	875[3,6], 500[3,8]	0	0%
Suspended Solids, Total (mg/l)	4	48	8	7	n.d.	32	158[1,6], 90[1,8]	0	0%
THM Formation Potential, Total	4	5	170	159	142	196			
Microcystin, Total (ug/l)	0.2	24	-----	n.d.	n.d.	14.0	-----	-----	-----

n.d. = Not detected.

[A] Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

[B] Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

[C] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[D] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- [2] South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- [3] Criteria for the protection of domestic water supply waters.
- [4] Criteria for the protection of agricultural water supply waters.
- [5] Criteria for the protection of commerce and industry waters.
- [6] Daily maximum criterion (monitoring results directly comparable to criterion).
- [7] Daily minimum criterion (monitoring results directly comparable to criterion).
- [8] 30-day average criterion (monitoring results not directly comparable to criterion).
- [9] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- [10] Nutrient criteria – Lewis and Clark Lake is classified R9 by Nebraska for application of nutrient criteria.

[E] A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

[F] According to South Dakota's beneficial use support decision criteria, dissolved oxygen levels are not considered impaired if a region exists in the depth profile (i.e., epilimnion) where the dissolved oxygen levels are ≥5 mg/l. Nebraska's dissolved oxygen criteria do not apply to the hypolimnion.

* The highlighted mean values indicate use impairment based on State of Nebraska 2008 Section 303(d) impairment assessment criteria.

Plate 335. Summary of monthly (June through September) water quality conditions monitored in Lewis and Clark Lake near the Weigand Recreation Area (site GPTLK0815DW) during the 2-year period 2008 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	9	1206.7	1206.7	1205.9	1207.5	-----	-----	-----
Water Temperature (°C)	0.1	87	21.1	22.1	14.1	25.3	27[1,2,6], 29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0.1	87	8.5	8.6	6.3	10.2	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	87	98.5	99.6	74.7	121.0	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	87	8.5	8.6	6.3	10.2	5[1,7]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0[F]	-----	-----	-----	-----	5[1,7]	-----	-----
Specific Conductance (umho/cm)	1	87	710	705	662	760	-----	-----	-----
pH (S.U.)	0.1	87	8.3	8.3	7.8	8.7	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Turbidity (NTUs)	1	87	22	18	3	77	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	87	342	338	269	439	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	87	26*	19	1	85	8[8]	76	87%
Secchi Depth (in)	1	9	24	22	19	38	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) Nutrient criteria – Lewis and Clark Lake is classified R9 by Nebraska for application of nutrient criteria.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

* The highlighted mean value indicates use impairment based on State of Nebraska 2008 Section 303(d) impairment assessment criteria.

Plate 336. Summary of monthly (May through September) water quality conditions monitored in Lewis and Clark Lake near the Bloomfield Recreation Area (Site GPTLK0819DW) during the 2-year period 2008 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	9	1206.7	1206.7	1205.9	1207.5	-----	-----	-----
Water Temperature (°C)	0.1	72	20.5	22.2	10.2	24.6	27[1,2,6], 29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0.1	72	902	809	5.1	13.3	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	72	105.9	105.6	58.9	156.2	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	69	9.4	9.0	6.4	13.3	5[1,7]	4	1%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	3	6.0	5.9	5.1	7.0	5[1,7]	0	0%
Specific Conductance (umho/cm)	1	72	712	710	636	769	2,000[4]	0	0%
pH (S.U.)	0.1	72	8.4	8.4	7.8	8.8	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Turbidity (NTUs)	1	65	25	22	2	123	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	72	347	345	274	456	-----	-----	-----
Secchi Depth (in.)	1	9	24	19	16	40	-----	-----	-----
Alkalinity, Total (mg/l)	7	18	156	157	148	164	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	18	3.8	3.2	2.4	9.2	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	18	14	13	6	29	-----	-----	-----
Chloride (mg/l)	1	18	12	12	8	14	438[3,6], 250[3,8]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	63	30*	23	8	138	8[10]	62	98%
Chlorophyll *a* (ug/l) – Lab Determined	1	9	29*	29	8	76	8[10]	8	89%
Color (S.U. - APHA)	1	9	7	8	4	11	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	18	482	467	430	568	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	18	-----	0.03	n.d.	0.18	3.9 [1,6,9], 0.75[1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	18	0.7	0.6	0.2	1.5	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	18	-----	n.d.	n.d.	0.50	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	18	0.77*	0.6	0.2	1.8	0.57[10]	10	56%
Phosphorus, Dissolved (mg/l)	0.02	17	-----	n.d.	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	18	0.06	0.06	0.02	0.15	0.06[10]	7	19%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	18	-----	n.d.	n.d.	0.07	-----	-----	-----
Sulfate (mg/l)	1	18	199	199	172	221	875[3,6], 500[3,8]	0	0%
Suspended Solids, Total (mg/l)	4	18	11	8	n.d.	25	158[1,6], 90[1,8]	0	0%
THM Formation Potential, Total	4	5	154	152	138	174	-----	-----	-----
Microcystin, Total (ug/l)	0.2	9	-----	n.d.	n.d.	0.2	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Nutrient criteria – Lewis and Clark Lake is classified R9 by Nebraska for application of nutrient criteria.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

* The highlighted mean values indicate use impairment based on State of Nebraska 2008 Section 303(d) impairment assessment criteria.

Plate 337. Summary of monthly (June through September) water quality conditions monitored in Lewis and Clark Lake near the Devils Nest Area (site GPTLK0822DW) during the 2-year period 2008 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-msl)	0.1	10	1206.7	1206.8	1205.9	1207.5	-----	-----	-----
Water Temperature (°C)	0.1	58	20.2	21.9	10.0	24.3	27[1,2,6], 29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0.1	58	9.2	8.7	6.2	13.6	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	58	104.7	104.3	73.6	138.2	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	58	9.2	8.7	6.2	13.6	5[1,7]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0[F]	-----	-----	-----	-----	5[1,7]	-----	-----
Specific Conductance (umho/cm)	1	58	714	709	647	765	-----	-----	-----
pH (S.U.)	0.1	58	8.4	8.4	7.9	8.7	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Turbidity (NTUs)	1	51	27	20	5	83	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	58	353	357	276	445	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	52	30*	26	4	81	8[8]	48	92%
Secchi Depth (in)	1	10	21	21	12	33	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) Nutrient criteria – Lewis and Clark Lake is classified R9 by Nebraska for application of nutrient criteria.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

* The highlighted mean value indicates use impairment based on State of Nebraska 2008 Section 303(d) impairment assessment criteria.

Plate 338. Summary of monthly (May through September) water quality conditions monitored in Lewis and Clark Lake near the Charley Creek Area (Site GPTLK0825DW) during the 2-year period 2008 through 2009.

	Monitoring Results[A]						Water Quality Standards Attainment		
Parameter	**Detection Limit[B]**	**No. of Obs.**	**Mean[C]**	**Median**	**Min.**	**Max.**	**State WQS Criteria[D]**	**No. of WQS Exceedances**	**Percent WQS Exceedance**
Pool Elevation (ft-msl)	0.1	10	1206.7	1206.8	1205.9	1207.5	-----	-----	-----
Water Temperature (°C)	0.1	39	20.4	21.7	14.0	24.2	27[1,2,6], 29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0.1	39	9.1	8.5	7.4	12.2	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	39	104.1	101.6	86.6	128.1	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	39	9.1	8.5	7.4	12.2	5[1,7]	4	1%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0[F]	-----	-----	-----	-----	5[1,7]	0	0%
Specific Conductance (umho/cm)	1	39	693	687	663	725	2,000[4]	0	0%
pH (S.U.)	0.1	39	8.3	8.4	8.0	8.5	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Turbidity (NTUs)	1	35	37	31	11	91	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	39	352	357	277	436	-----	-----	-----
Secchi Depth (in.)	1	10	16	14	9	24	-----	-----	-----
Alkalinity, Total (mg/l)	7	9	158	158	150	172	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	9	3.9	3.8	1.8	8.3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	9	13	11	8	23	-----	-----	-----
Chloride (mg/l)	1	9	12	11	11	14	438[3,6], 250[3,8]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	34	28*	23	8	50	8[10]	34	100%
Chlorophyll *a* (ug/l) – Lab Determined	1	9	26*	20	9	46	8[10]	9	100%
Color (S.U. - APHA)	1	4	7	9	n.d.	9	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	9	464	448	432	542	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	9	-----	n.d.	n.d.	0.09	3.9[1,6,9], 0.77[1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	9	0.8	0.6	0.4	1.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	9	-----	0.06	n.d.	0.25	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	9	0.9*	0.7	0.4	1.5	0.57[10]	7	78%
Phosphorus, Dissolved (mg/l)	0.02	8	-----	n.d.	n.d.	0.06	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	9	0.07*	0.07	n.d.	0.16	0.06[10]	7	19%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	9	-----	n.d.	n.d.	0.05	-----	-----	-----
Sulfate (mg/l)	1	9	188	188	175	205	875[3,6], 500[3,8]	0	0%
Suspended Solids, Total (mg/l)	4	9	25	24	11	52	158[1,6], 90[1,8]	0	0%
THM Formation Potential, Total	4	5	156	154	151	167	-----	-----	-----
Microcystin, Total (ug/l)	0.2	9	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Nutrient criteria – Lewis and Clark Lake is classified R9 by Nebraska for application of nutrient criteria.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

* The highlighted mean values indicate use impairment based on State of Nebraska 2008 Section 303(d) impairment assessment criteria.

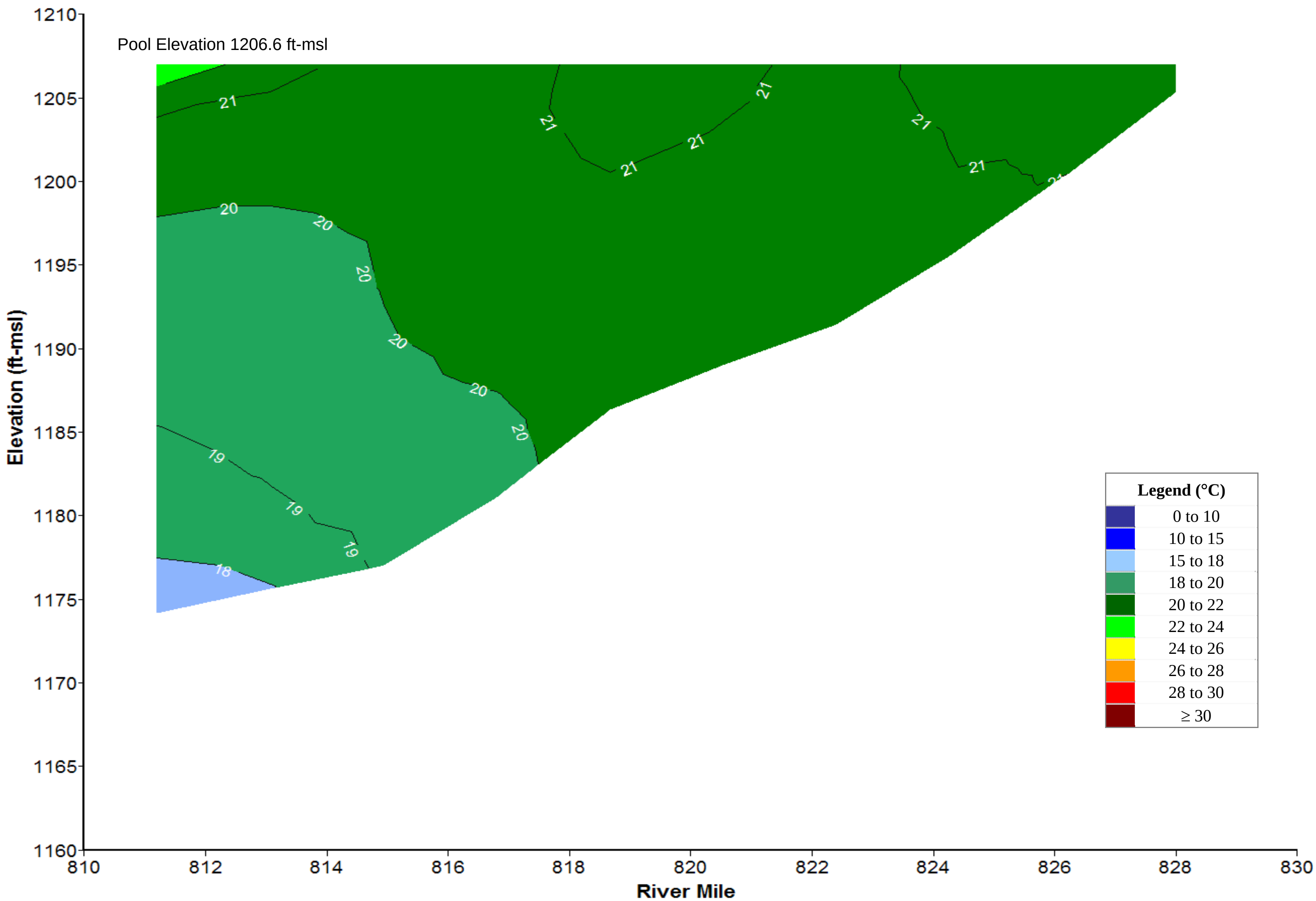


Plate 339. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 18, 2009.

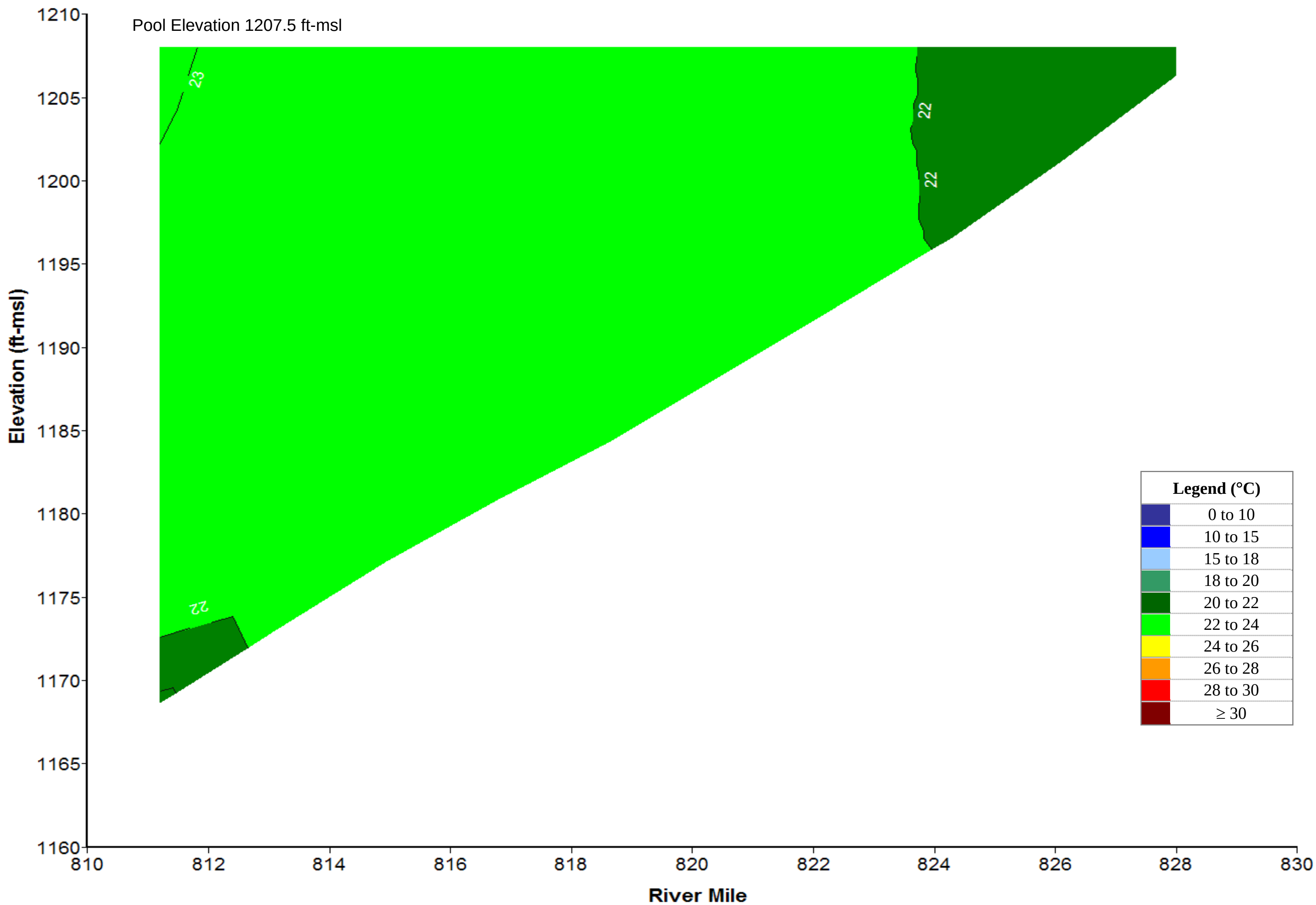


Plate 340. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 16, 2009.

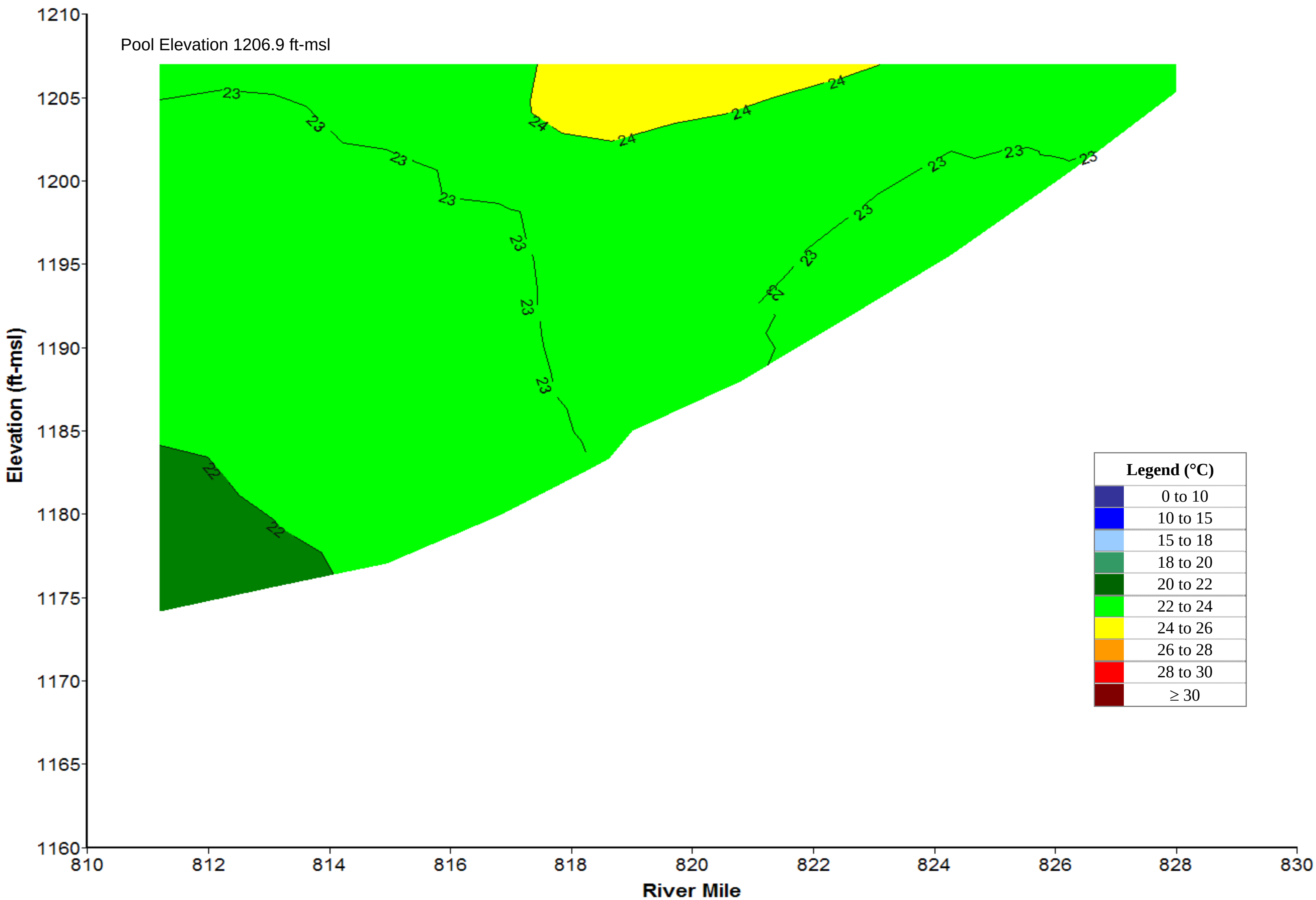


Plate 341. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 27, 2009.

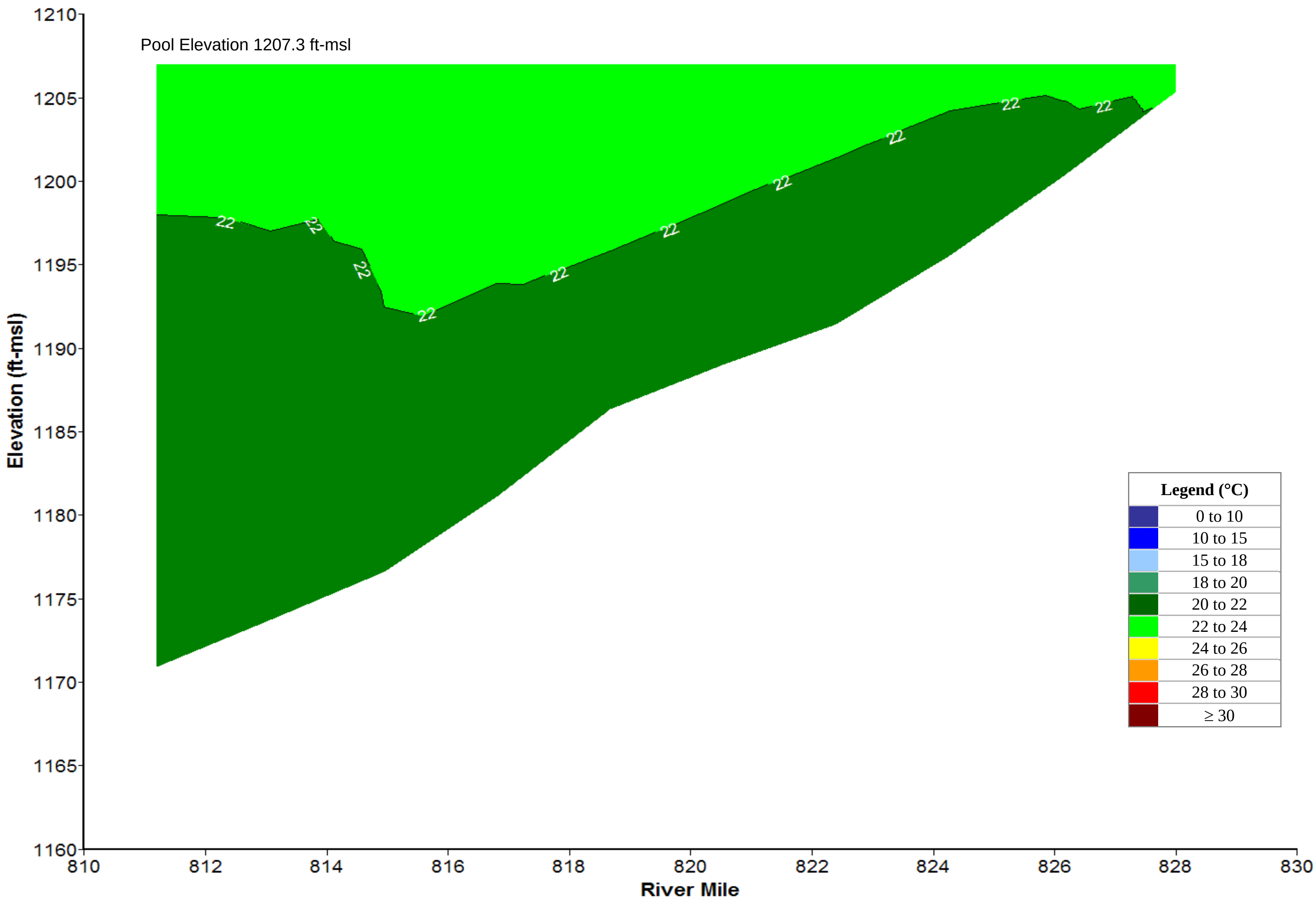


Plate 342. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 17, 2009**.**

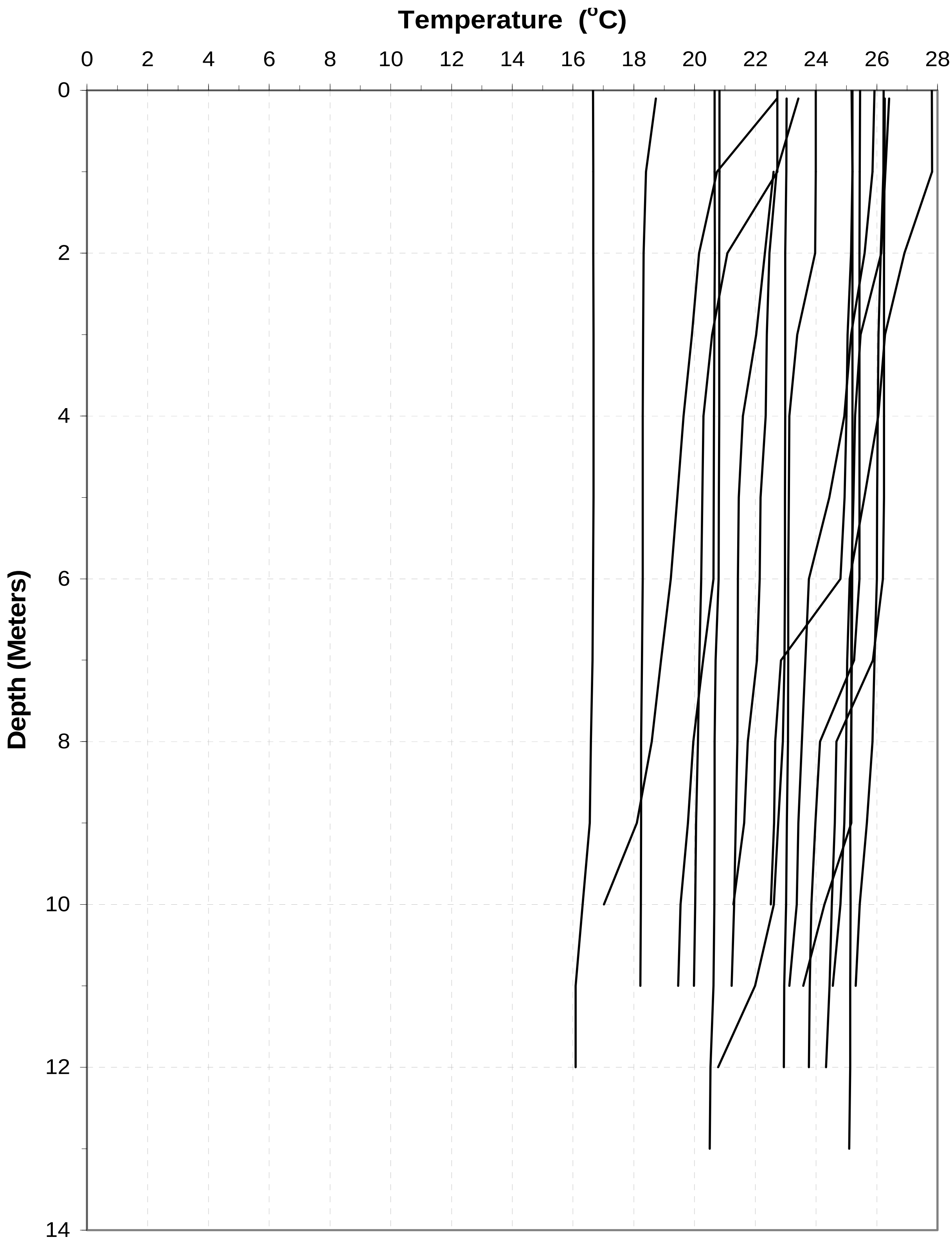


Plate 343. Temperature depth profiles for Lewis and Clark Lake generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., site GPTLK0811A) during the summer months over the 5-year period 2005 to 2009.

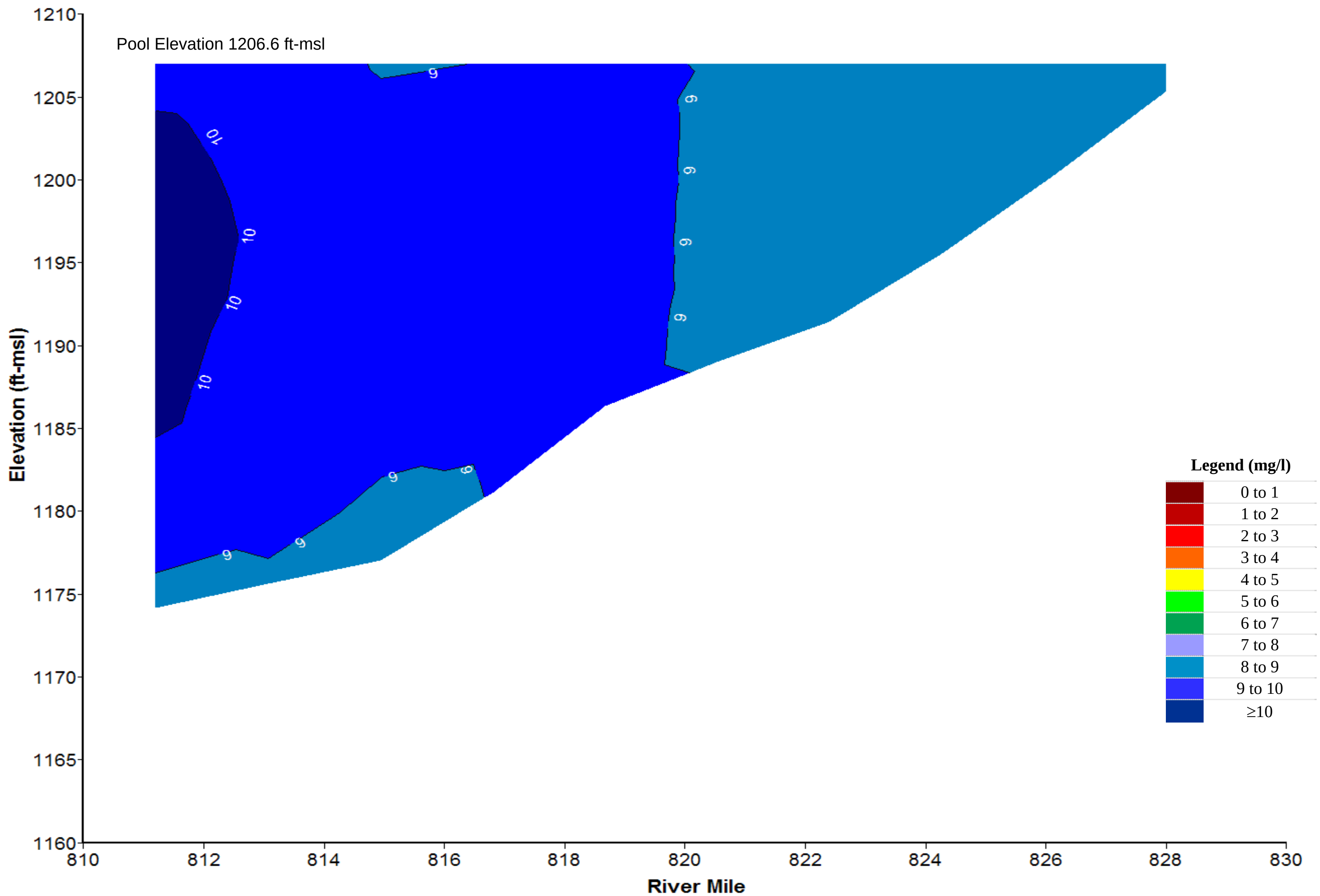


Plate 344. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 18, 2009.

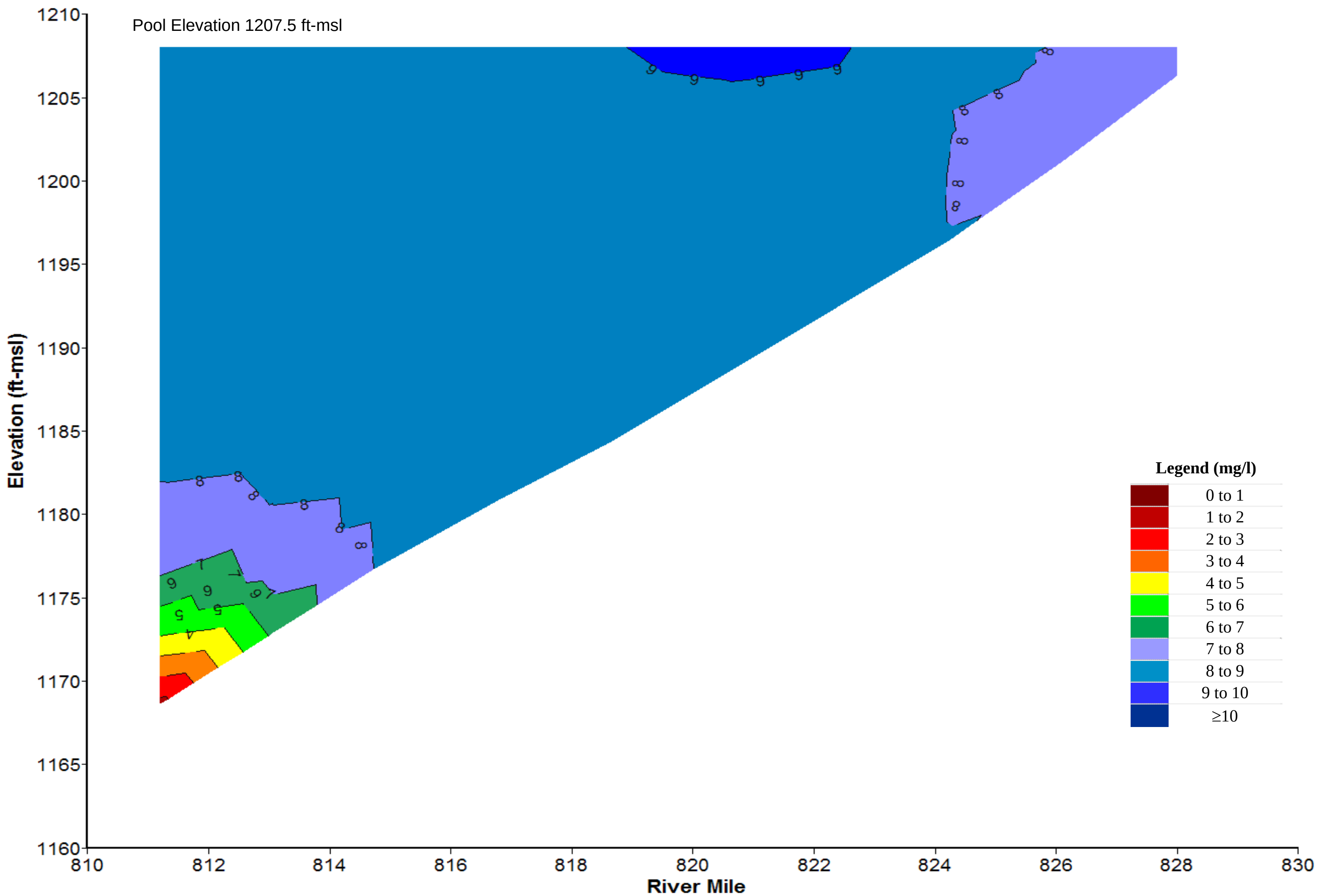


Plate 345. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 16, 2009.

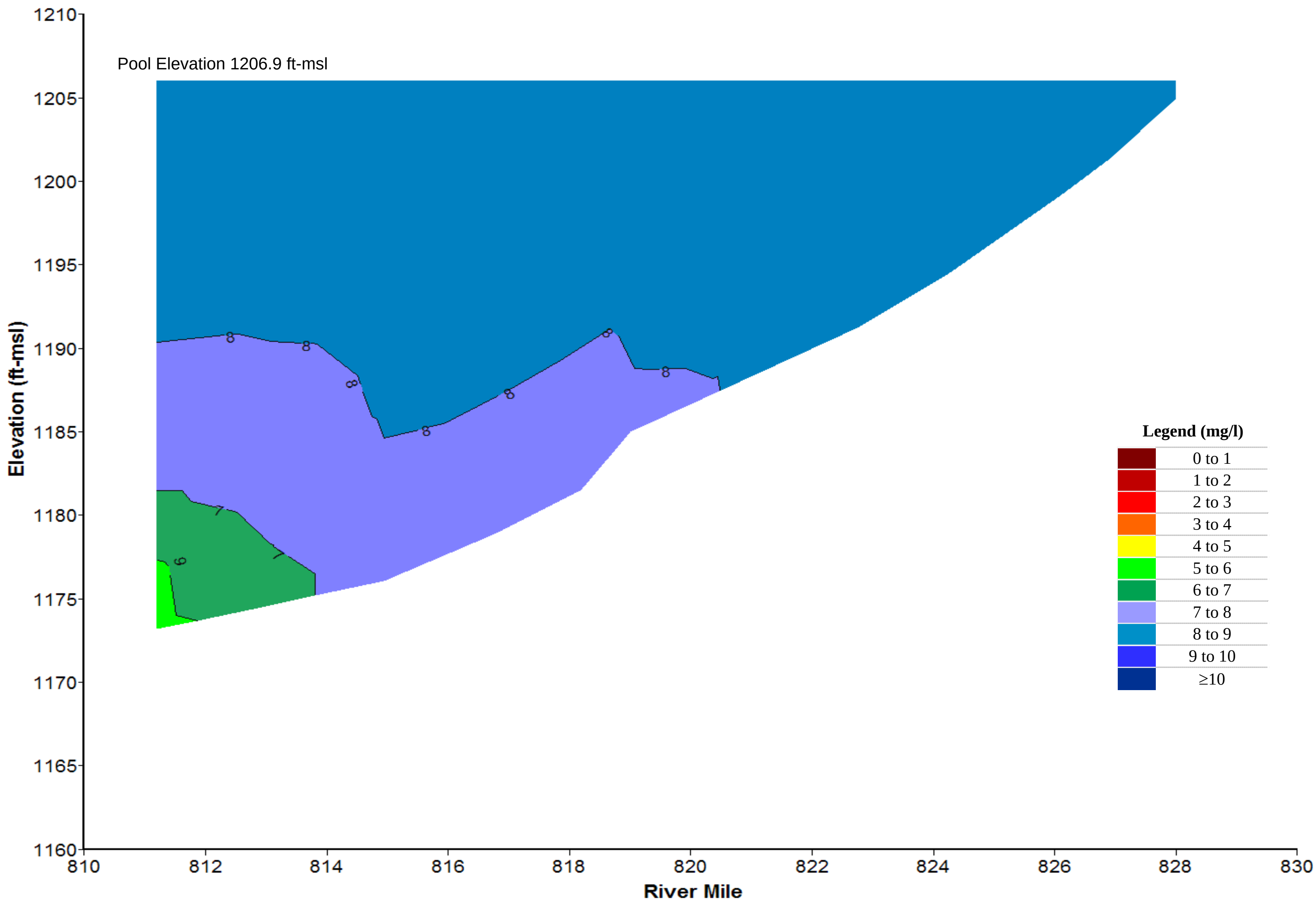


Plate 346. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 27, 2009.

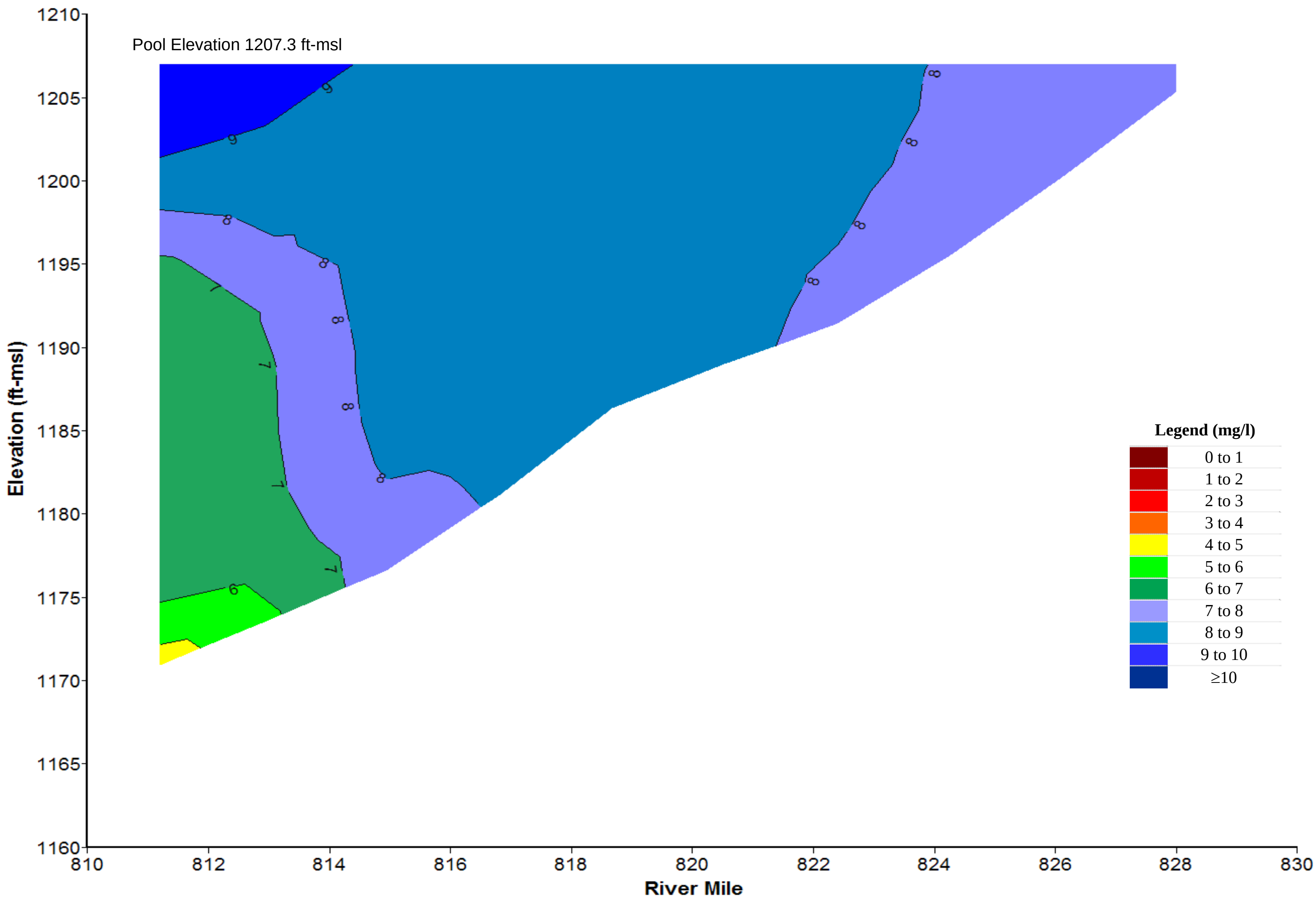


Plate 347. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 17, 2009.

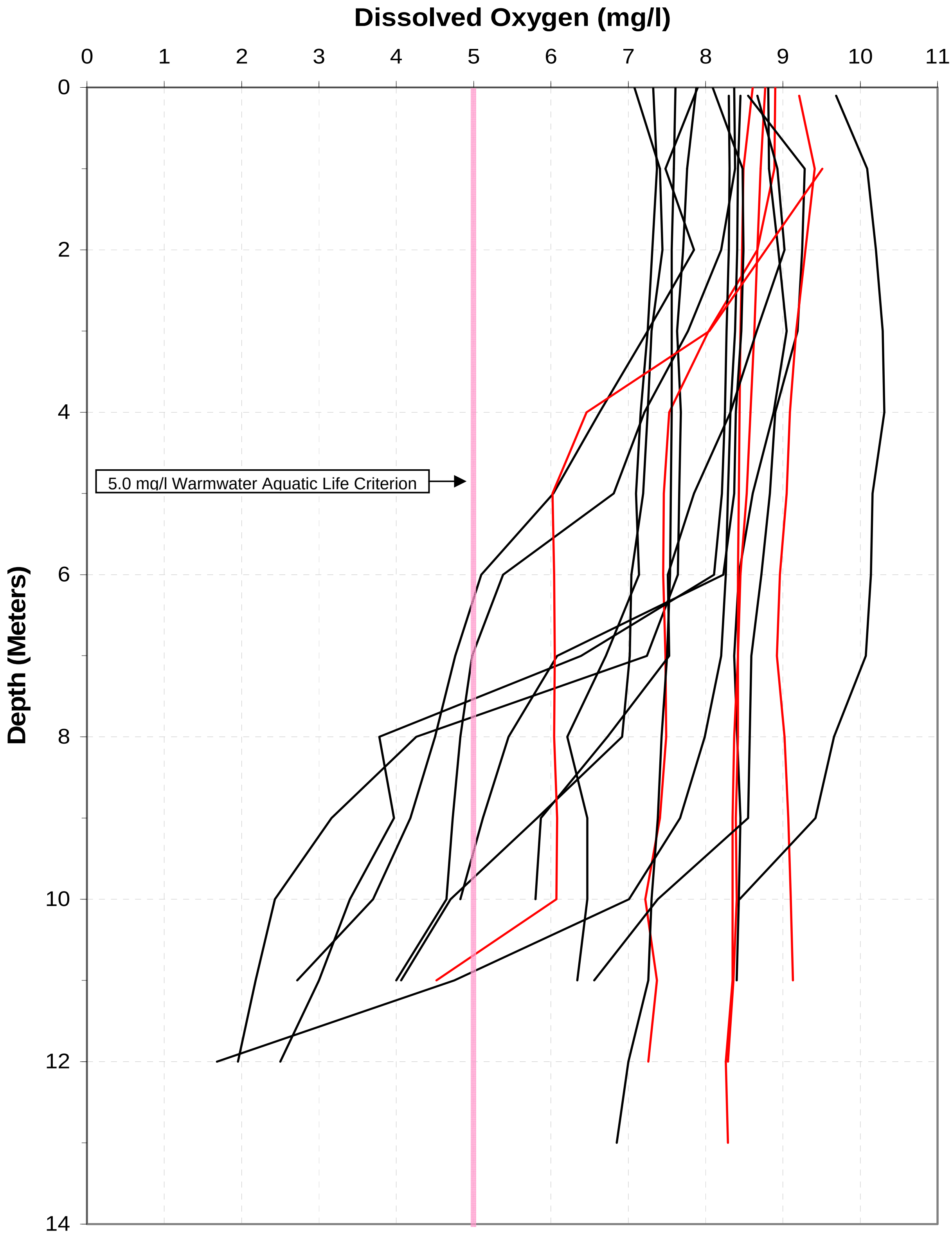


Plate 348. Dissolved oxygen depth profiles for Lewis and Clark Lake generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., site GPTLK0811A) during the summer months over the 5-year period 2005 to 2009.
(Note: Red profile plots were measured in the month of September.)

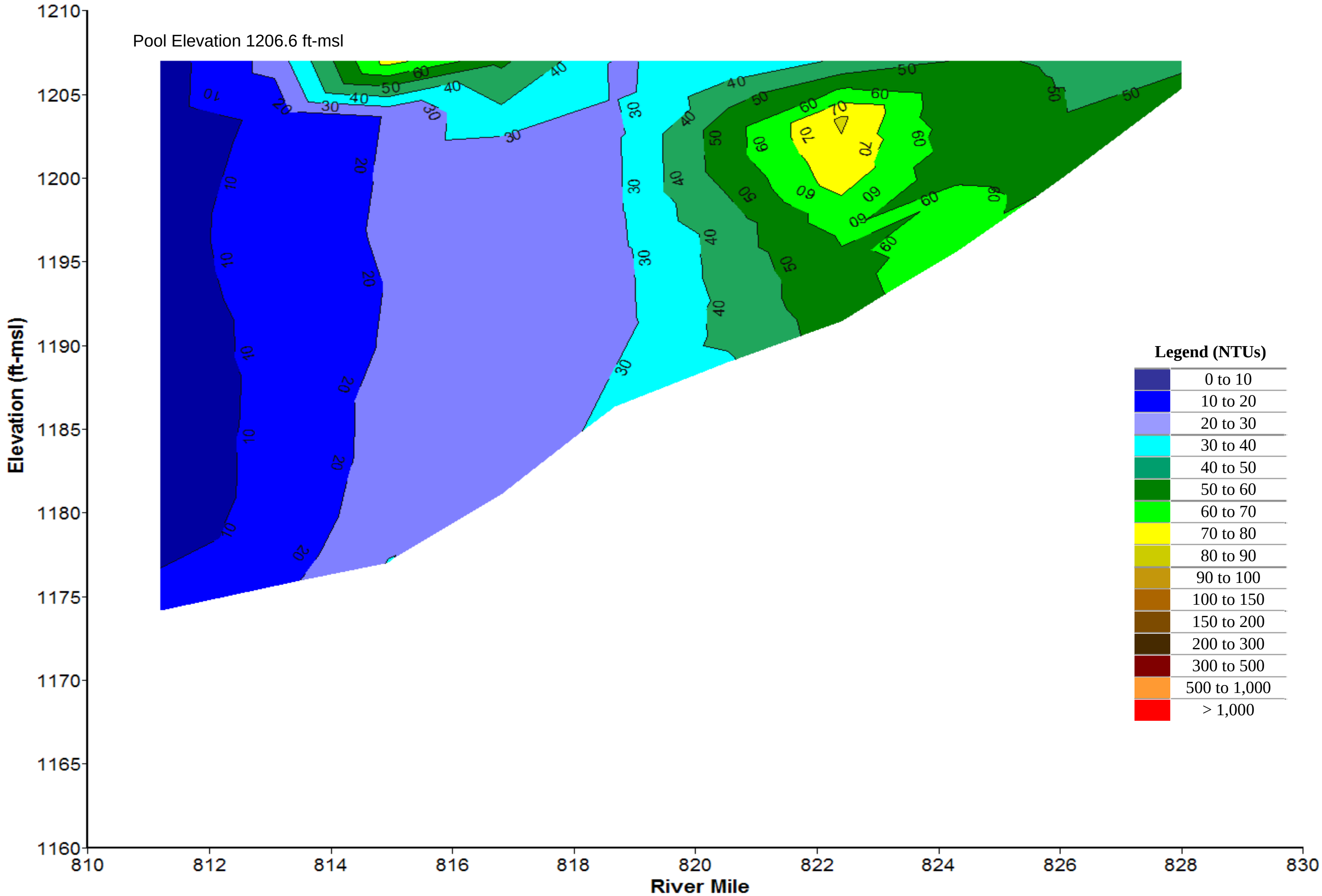


Plate 349. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 18, 2009.

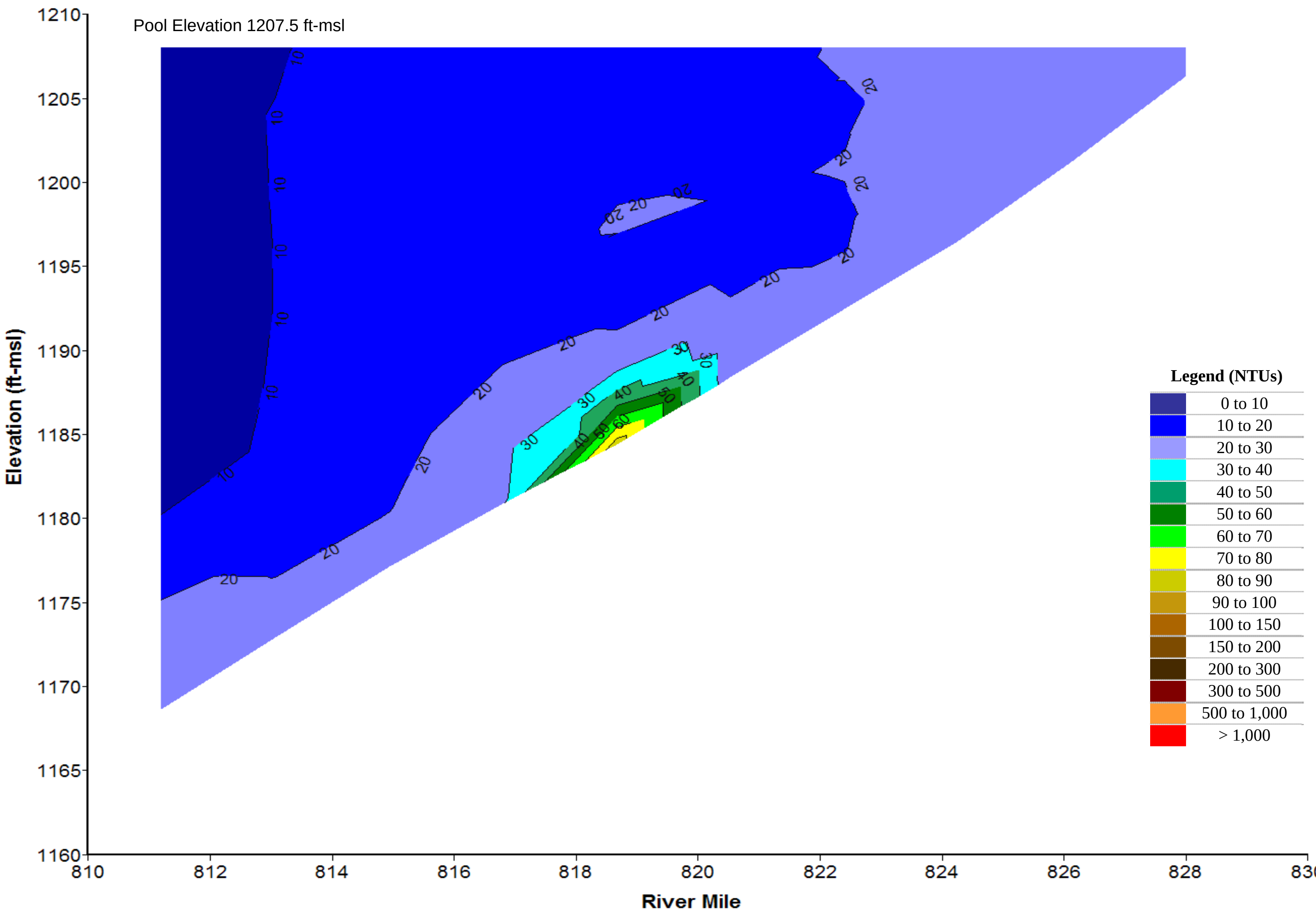


Plate 350. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 16, 2009.

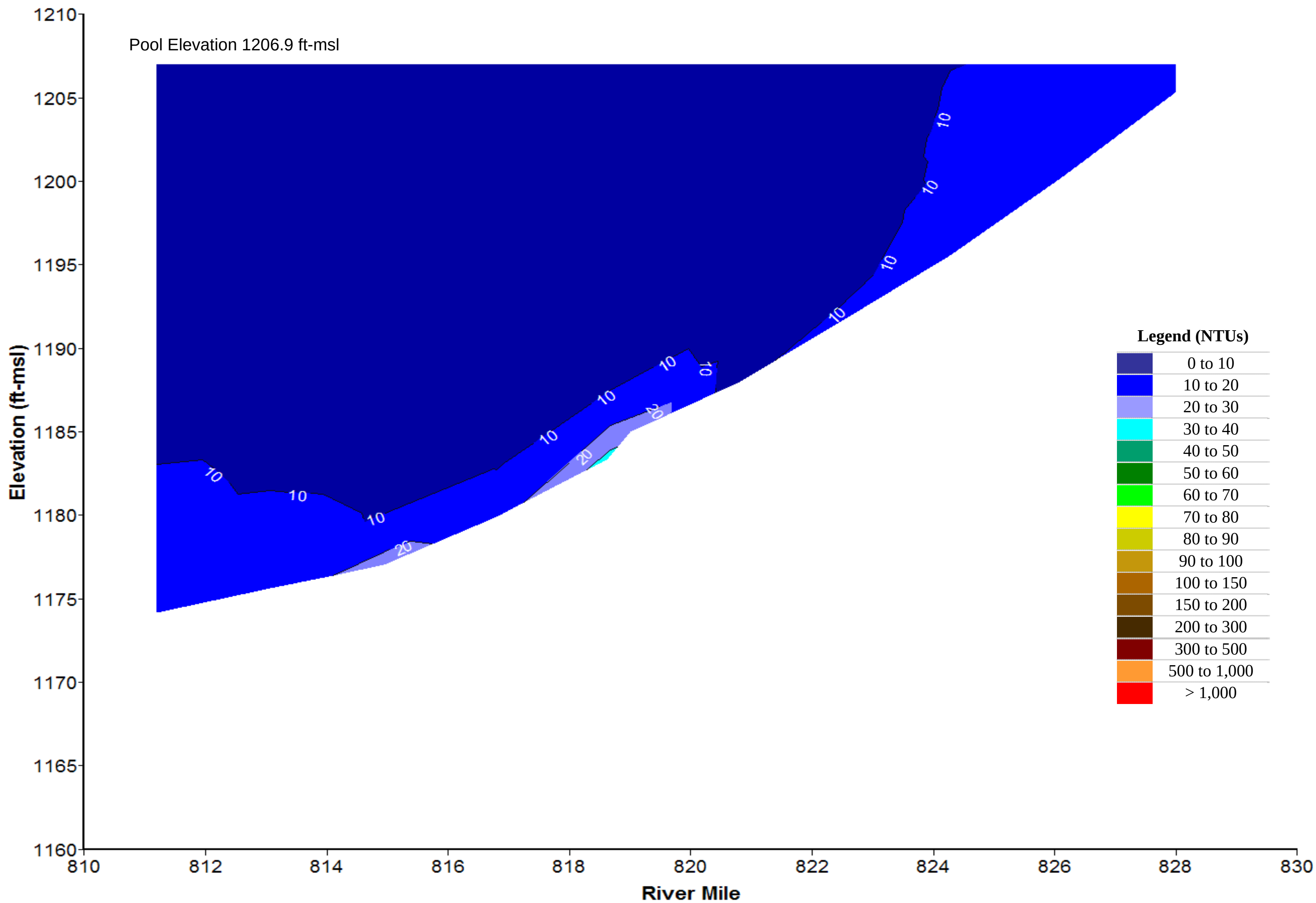


Plate 351. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 27, 2009.

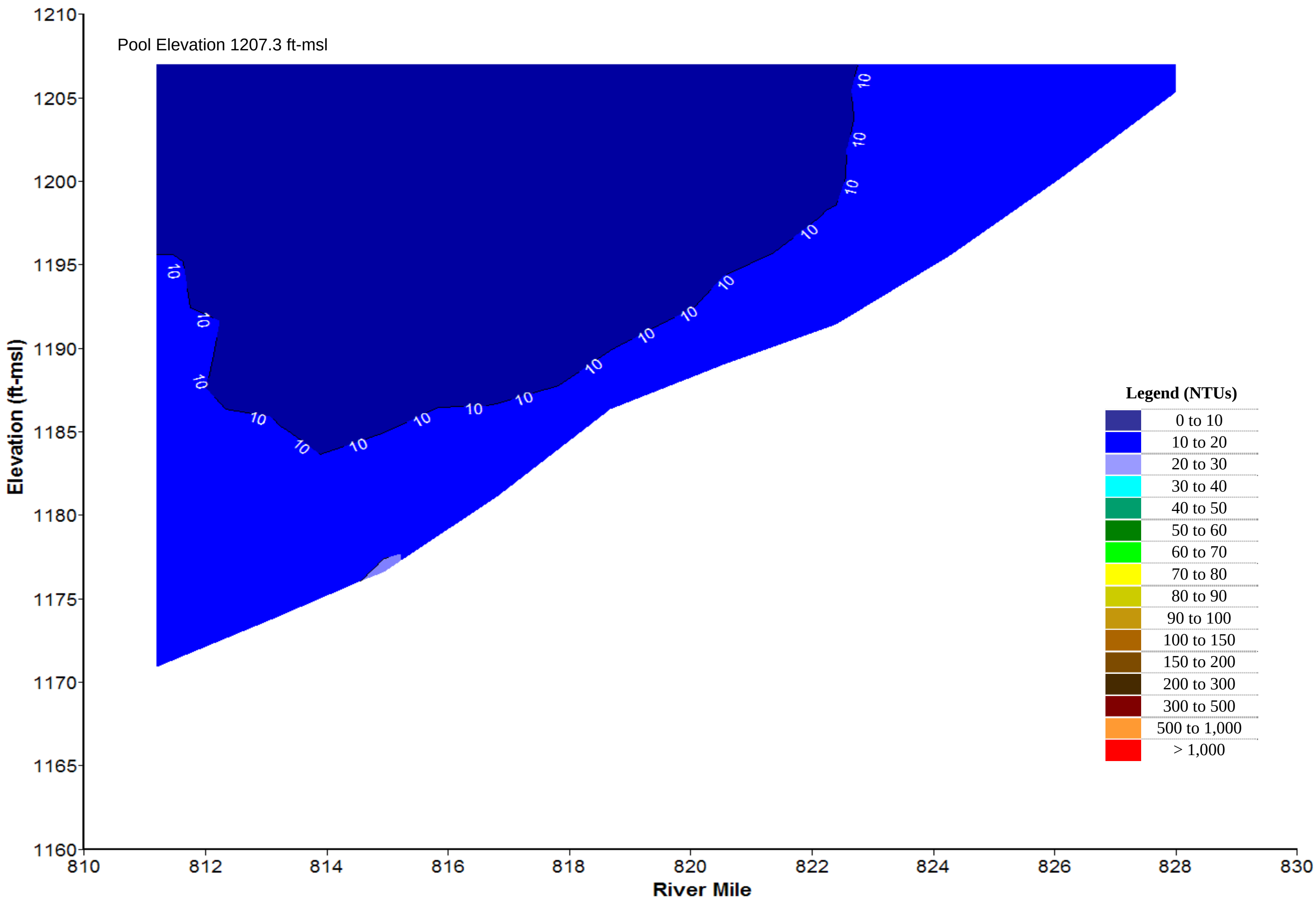


Plate 352. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 17, 2009**.**

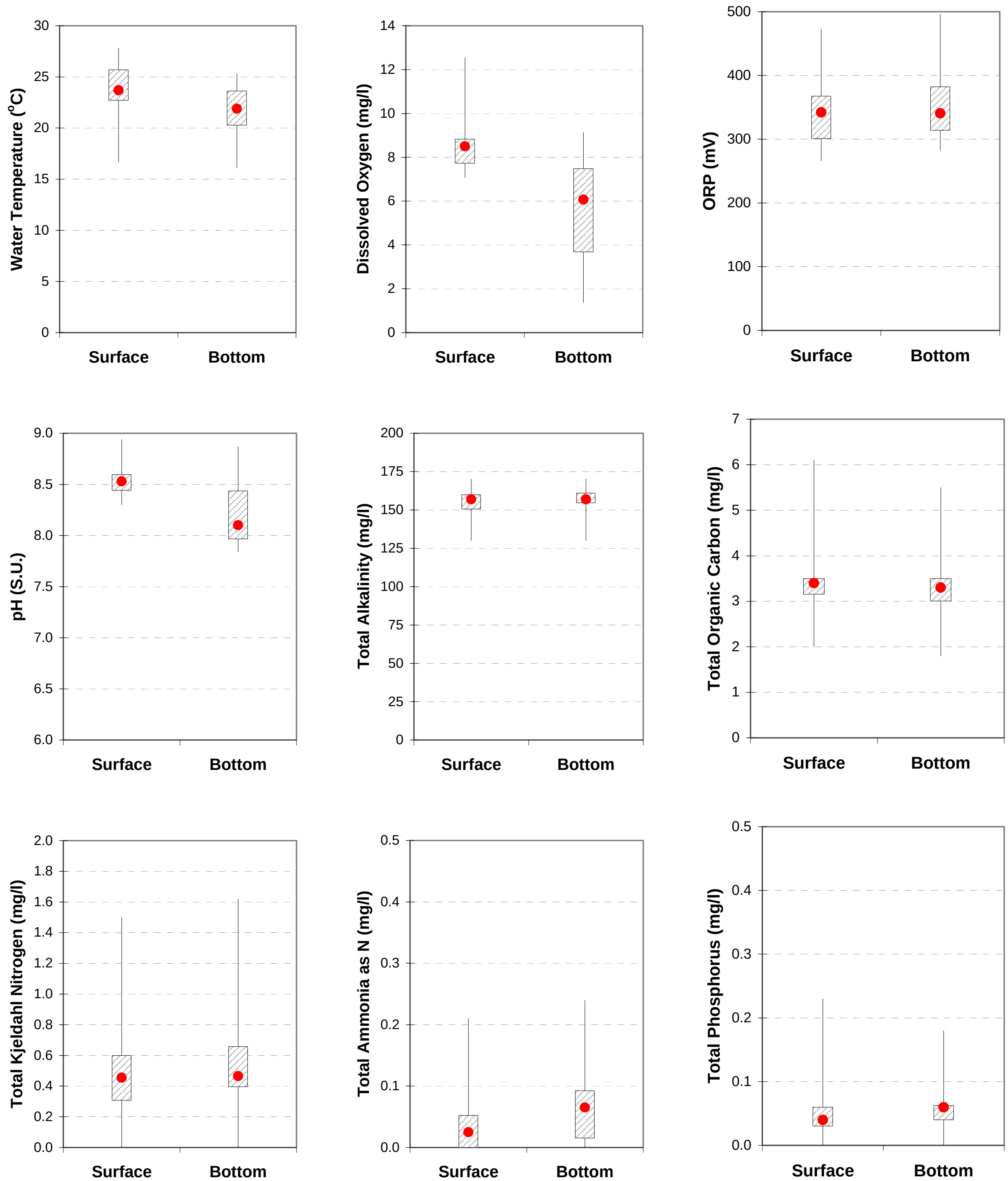


Plate 353. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Lewis and Clark Lake at site GPTLK0811A during the summer months of 2005 through 2009.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 354. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected at the near-dam, deepwater ambient monitoring site (i.e., site GPTLK0811A) at Lewis and Clark Lake during the 5-year period 2005 through 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
May 2005	170,642,733	6	0.86	3	0.08	0	-----	1	0.05	1	<0.01	0	-----	0	-----	1.29
Jun 2005	75,346,609	3	0.78	3	0.03	0	-----	1	0.15	3	<0.01	1	0.03	0	-----	1.35
Jul 2005	621,134,038	10	0.93	3	0.06	1	<0.01	1	<0.01	3	<0.01	0	-----	0	-----	1.61
Aug 2005	400,199,396	7	0.55	6	0.02	2	0.05	1	0.26	4	0.04	3	0.06	2	0.04	2.28
Sep 2005	337,716,027	11	0.49	10	0.04	0	-----	2	0.37	6	0.03	2	0.06	2	0.01	2.21
May 2006	1,170,506,627	12	0.97	13	0.01	0	-----	1	<0.01	2	<0.01	0	-----	2	0.01	1.19
Jun 2006	280,054,880	10	0.78	17	0.16	2	0.01	1	0.01	0	-----	1	0.03	1	0.01	2.15
Jul 2006	710,790,547	15	0.89	9	0.06	1	<0.01	1	<0.01	1	<0.01	3	0.04	1	0.01	2.01
Aug 2006	528,360,481	13	0.75	11	0.10	1	<0.01	1	<0.01	8	0.11	1	0.01	2	0.02	2.52
Sep 2006	520,570,174	19	0.72	22	0.22	0	-----	1	0.01	4	0.03	0	-----	2	0.02	2.84
May 2007	3,539,604,890	10	0.90	10	0.09	0	-----	1	<0.01	0	-----	0	-----	0	-----	1.32
Jun 2007	1,242,668,868	11	0.83	4	0.11	2	0.03	2	0.02	1	<0.01	1	<0.01	0	-----	1.83
Jul 2007	876,807,100	8	0.92	9	0.05	1	<0.01	1	0.03	0	-----	1	<0.01	0	-----	1.44
Aug 2007	674,471,295	8	0.69	11	0.06	0	-----	2	0.02	4	0.03	2	0.18	1	0.01	2.12
Sep 2007	2,492,800,160	12	0.88	13	0.02	0	-----	1	0.01	5	0.10	1	<0.01	2	<0.01	1.67
May 2008	1,995,694,814	13	1.00	3	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	1	<0.01	1.07
Jun 2008	1,260,870	9	0.70	10	0.17	1	<0.01	1	0.13	1	<0.01	1	<0.01	0	-----	1.68
Jul 2008	1,908,747	23	0.98	12	0.01	3	<0.01	1	<0.01	6	<0.01	1	<0.01	1	<0.01	1.03
Aug 2008	772,197,225	6	0.88	11	0.01	2	<0.01	1	0.08	4	0.02	1	<0.01	2	0.01	1.19
Sep 2008	670,486,456	10	0.92	19	0.02	0	<0.01	2	0.05	4	<0.01	2	<0.01	1	<0.01	1.17
May 2009	23,766,000,816	19	0.93	8	0.02	2	<0.01	2	0.05	1	<0.01	1	<0.01	1	<0.01	1.42
Jun 2009	2,071,132	9	0.99	11	0.01	0	-----	0	-----	1	<0.01	0	-----	1	<0.01	1.04
Jul 2009	2,212,544,139	13	0.91	9	0.04	0	-----	1	0.05	0	-----	1	<0.01	1	<0.01	1.18
Aug 2009	1,046,854,773	9	0.35	8	0.09	2	0.05	1	0.18	5	0.05	2	0.27	0	-----	2.18
Sep 2009	1,688,840,751	10	0.24	7	0.09	1	0.04	1	0.52	7	0.08	2	0.03	2	<0.01	2.09
Mean	**1,831,981,342**	**11.0**	**0.79**	**9.7**	**0.06**	**0.9**	**0.01**	**1.2**	**0.08**	**2.8**	**0.02**	**1.1**	**0.04**	**1.0**	**0.01**	**1.68**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 355. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected from the middle reaches of Lewis and Clark Lake (i.e., site GPTLK0819DW) during 2008 and 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2008	2,059,796	10	0.58	15	0.10	2	<0.01	1	0.30	2	0.02	1	<0.01	1	<0.01	1.61
Jul 2008	855,766	10	0.86	15	0.06	1	<0.01	1	0.05	4	<0.01	1	0.01	2	0.01	1.61
Aug 2008	288,837,035	7	0.77	10	0.06	1	<0.01	1	0.15	2	<0.01	1	0.01	1	0.01	2.47
Sep 2008	385,615,085	11	0.92	14	0.05	0	-----	1	<0.01	3	0.01	3	0.02	1	<0.01	1.39
May 2009	8,808,651,219	17	0.73	9	0.04	1	<0.01	2	0.23	0	-----	0	-----	0	-----	1.69
Jun 2009	2,036,622,095	29	0.92	7	0.08	1	<0.01	1	<0.01	0	-----	0	-----	0	-----	1.45
Jul 2009	1,112,124,499	15	0.68	10	0.15	0	-----	1	0.16	1	<0.01	1	<0.01	1	0.01	2.17
Aug 2009	306,710,867	12	0.57	11	0.15	1	0.13	1	0.09	5	0.06	1	<0.01	0	-----	2.40
Sep 2009	2,239,418,220	21	0.67	12	0.08	1	<0.01	2	0.20	3	0.04	0	-----	3	<0.01	2.05
Mean	**1,686,766,065**	**14.7**	**0.74**	**11.4**	**0.09**	**0.9**	**0.02**	**1.2**	**0.13**	**2.2**	**0.02**	**0.9**	**0.01**	**1.0**	**0.01**	**1.87**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 356. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected from the upper reaches of Lewis and Clark Lake (i.e., site GPTLK0825DW) during 2008 and 2009.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2008	766,291	19	0.68	16	0.12	3	0.02	1	0.16	2	<0.01	1	<0.01	1	<0.01	2.20
Jul 2008	361,386	17	0.62	12	0.15	1	<0.01	1	0.23	4	<0.01	0	-----	0	-----	1.86
Aug 2008	113,583,376	13	0.67	5	0.07	0	-----	1	0.24	1	<0.01	0	-----	1	0.02	2.00
Sep 2008	589,971,711	10	0.70	16	0.13	0	-----	2	0.14	4	<0.01	2	0.03	1	<0.01	1.65
May 2009	2,220,300,470	30	0.88	9	0.04	1	<0.01	2	0.08	0	-----	0	-----	0	-----	2.66
Jun 2009	4,021,763,962	31	0.62	7	0.38	0	-----	0	-----	0	-----	1	<0.01	0	-----	2.15
Jul 2009	1,759,666,275	27	0.91	6	0.02	0	-----	2	0.06	0	-----	2	0.01	2	<0.01	2.75
Aug 2009	1,276,887,660	19	0.67	14	0.20	0	-----	1	0.11	3	<0.01	1	0.02	1	<0.01	2.61
Sep 2009	1,081,948,395	25	0.60	11	0.12	0	-----	1	0.20	5	0.06	0	-----	1	0.02	2.69
Mean	**1,229,472,170**	**21.2**	**0.71**	**10.7**	**0.14**	**0.6**	**0.01**	**1.2**	**0.15**	**2.1**	**0.01**	**0.8**	**0.01**	**0.8**	**0.01**	**2.29**

* Mean percent composition represents the mean when taxa of that division are present.

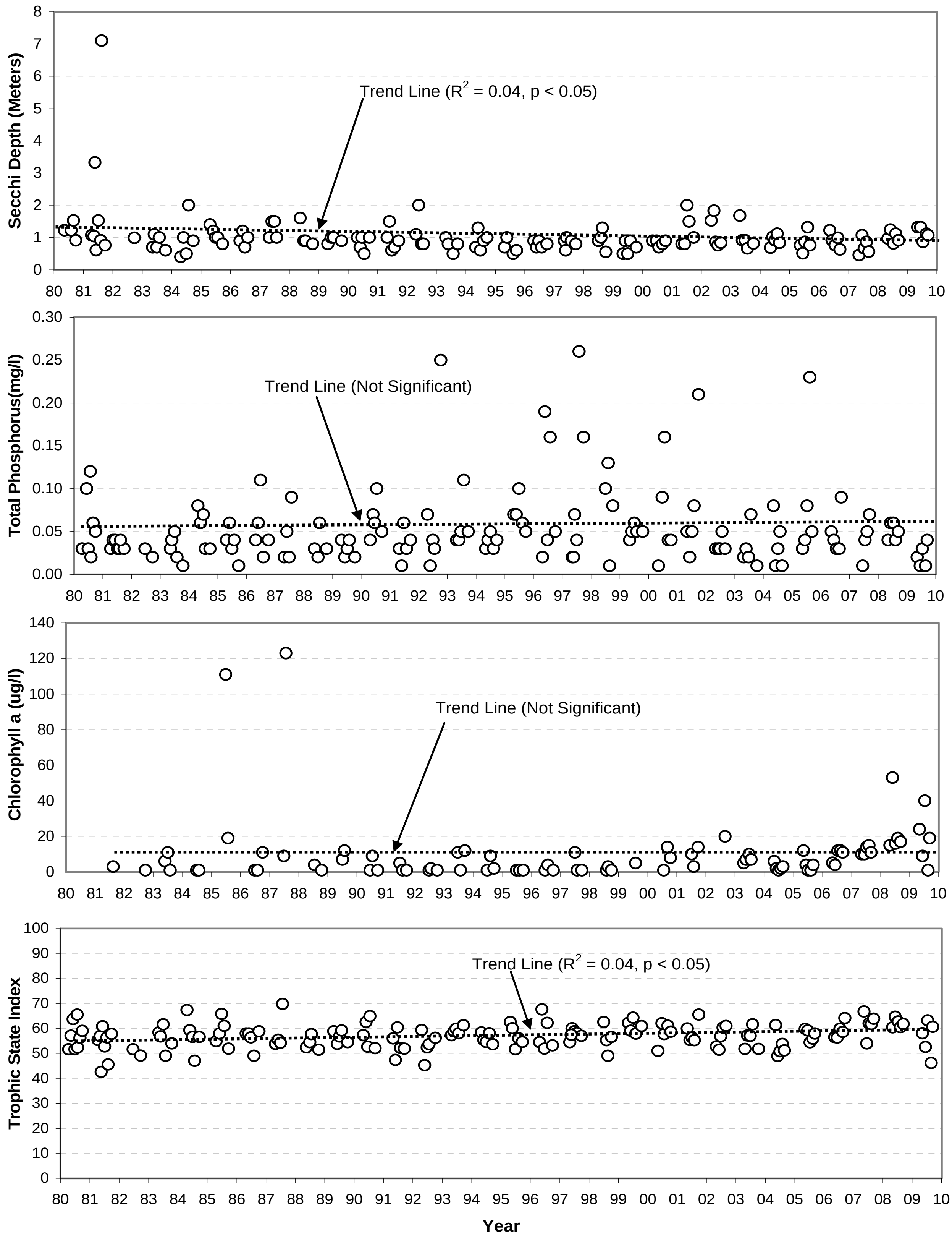


Plate 357. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Lewis and Clark Lake at the near-dam, ambient site (i.e., site GTPLK0811A) over the 30-year period of 1980 through 2009.

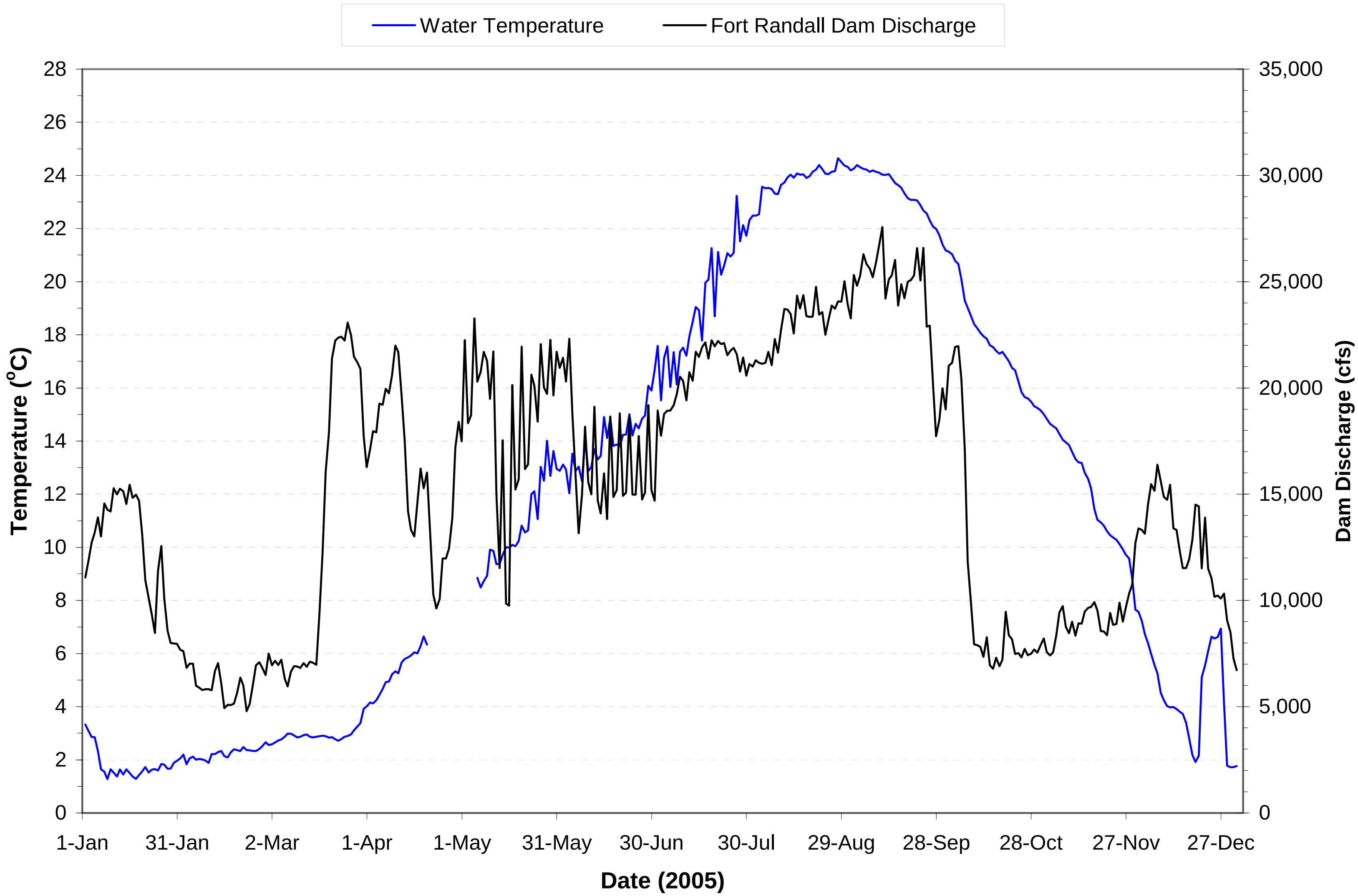


Plate 358. Mean daily water temperature and discharge of the Missouri River at Fort Randall Dam (i.e., site FTRPP1) for 2005. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Fort Randall Dam.
Note: Gaps in temperature plot are periods when monitoring equipment was not operational.

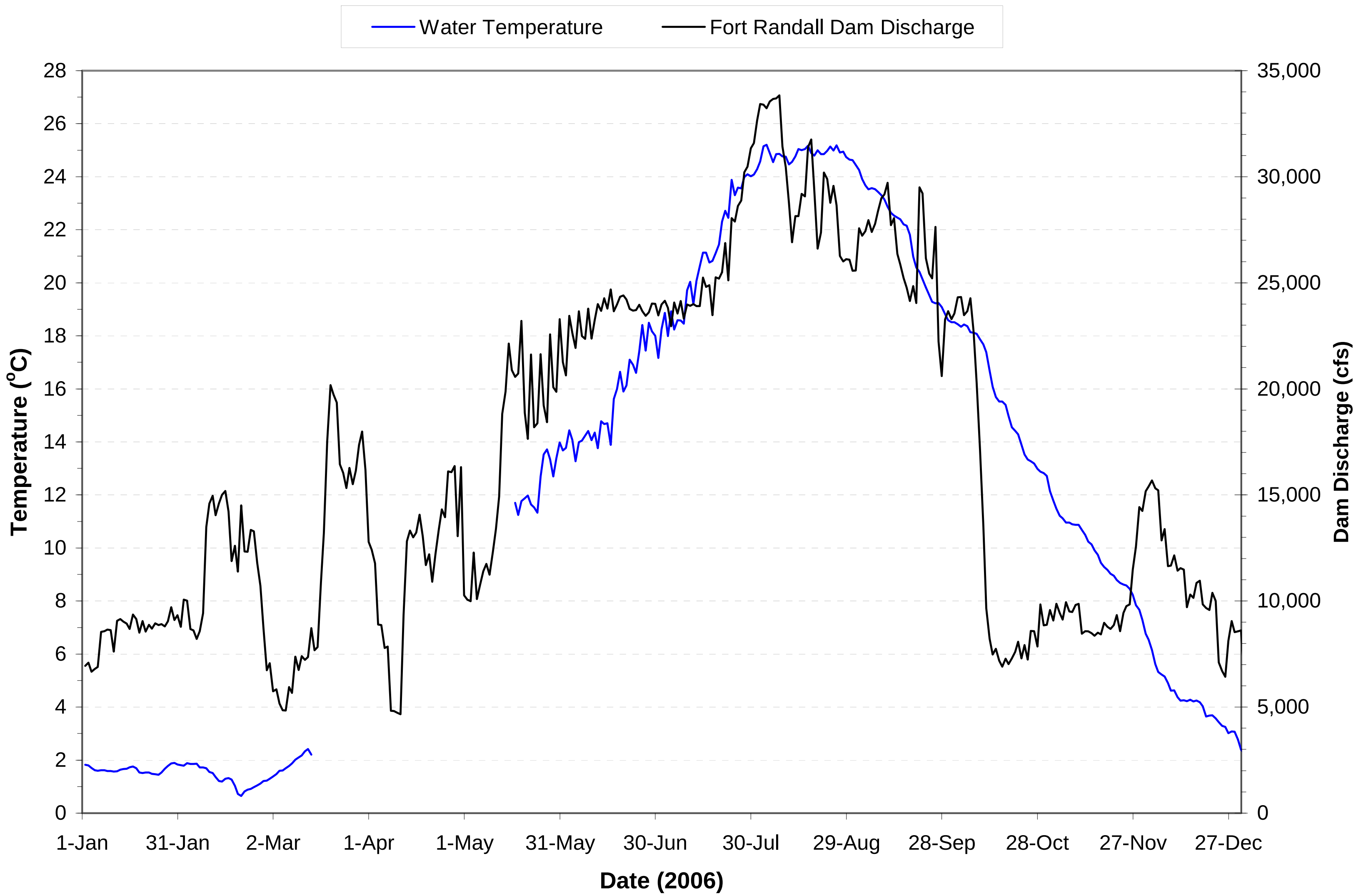


Plate 359. Mean daily water temperature and discharge of the Missouri River at Fort Randall Dam (i.e., site FTRPP1) for 2006. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Fort Randall Dam.
Note: Gaps in temperature plot are periods when monitoring equipment was not operational.

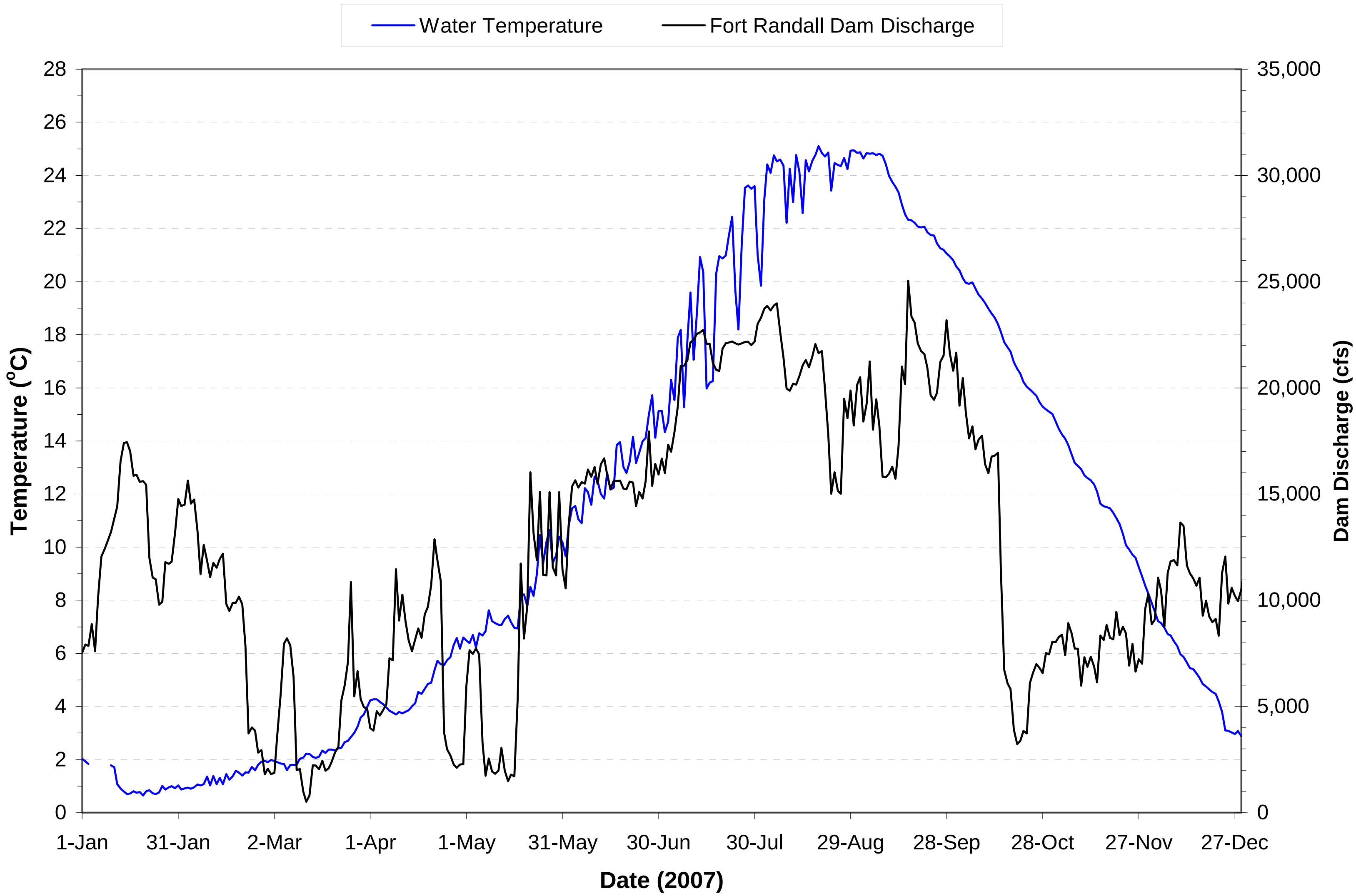


Plate 360. Mean daily water temperature and discharge of the Missouri River at Fort Randall Dam (i.e., site FTRPP1) for 2007. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Fort Randall Dam.

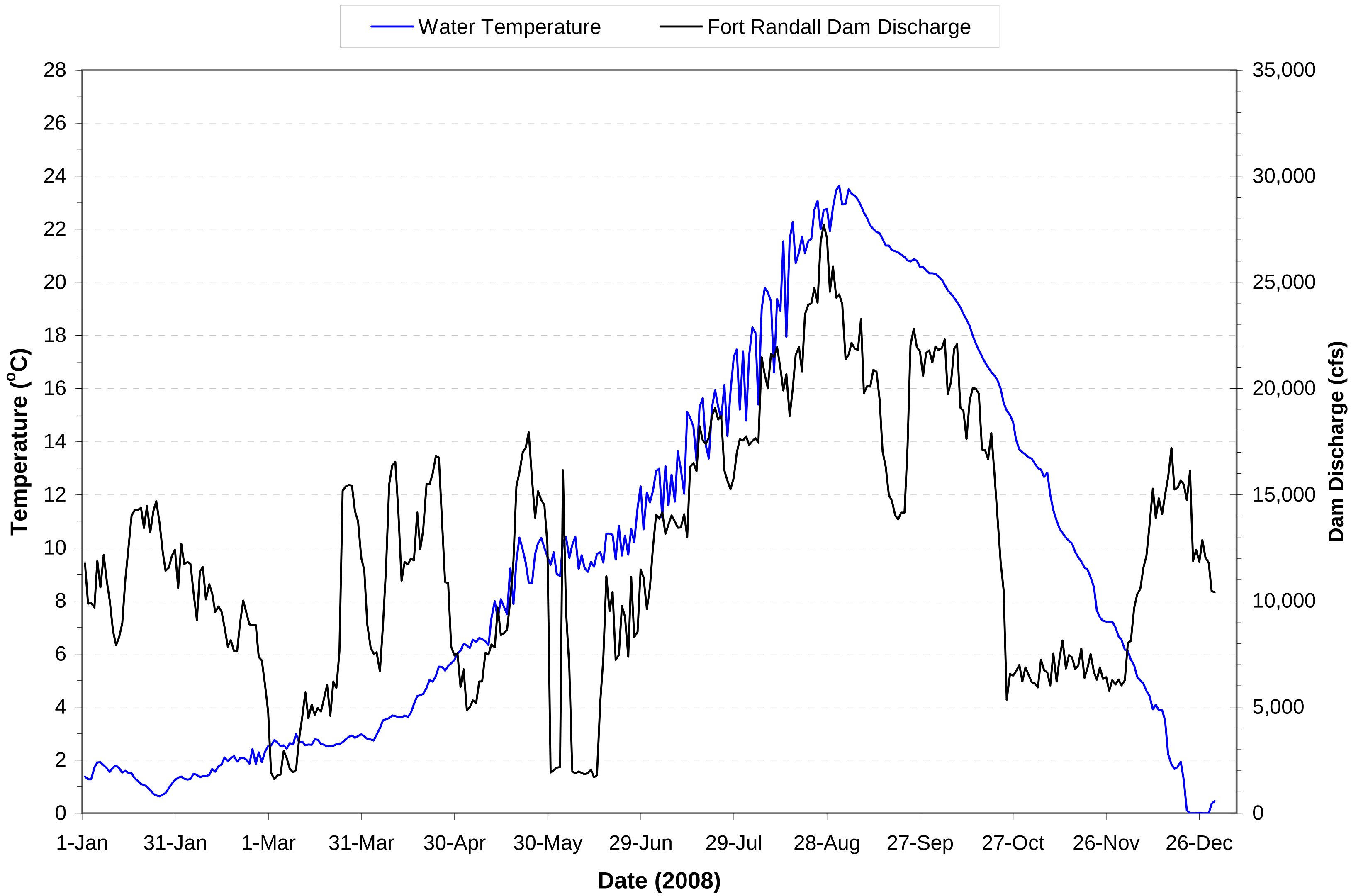


Plate 361. Mean daily water temperature and discharge of the Missouri River at Fort Randall Dam (i.e., site FTRPP1) for 2008. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Fort Randall Dam.

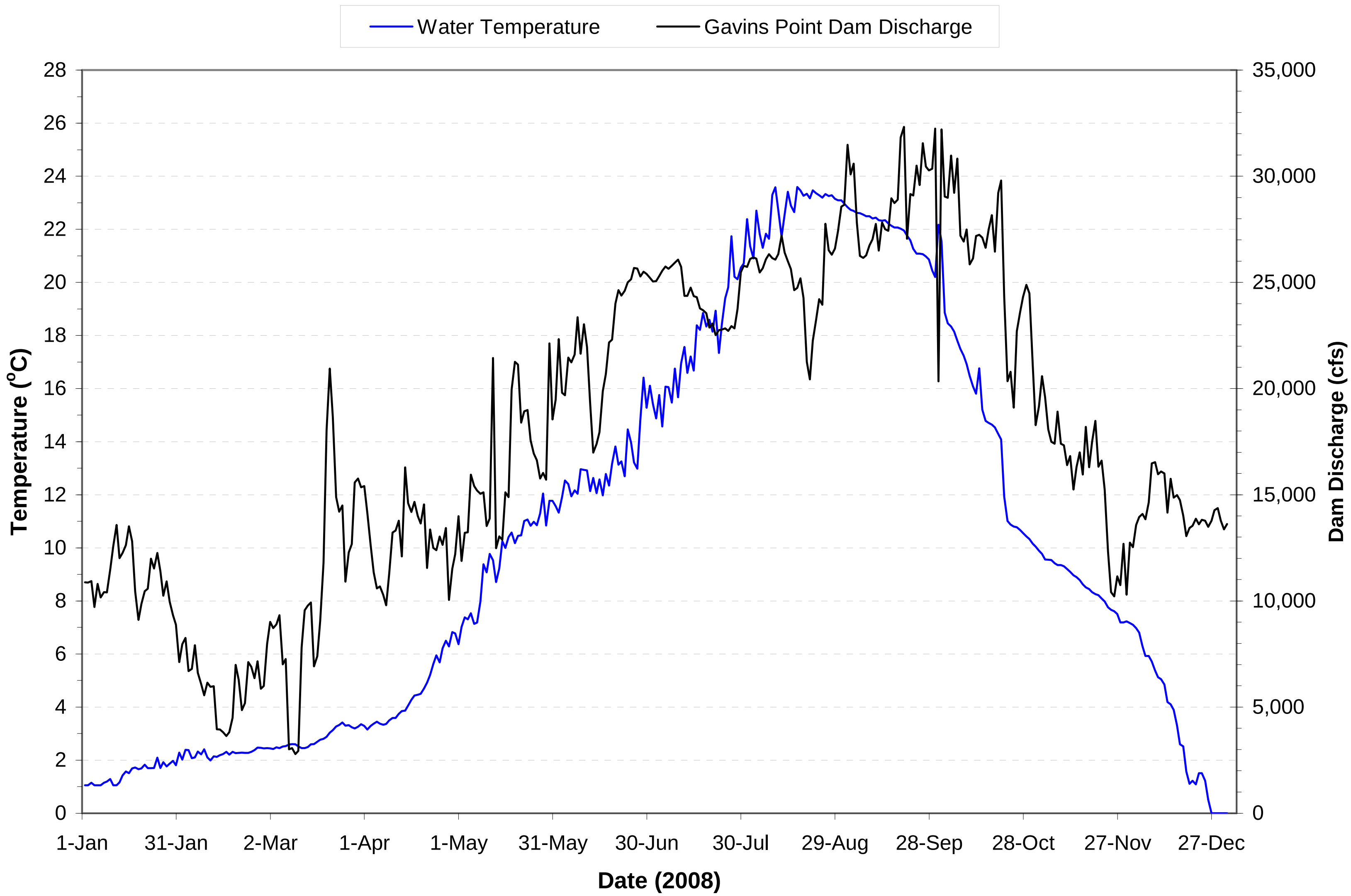


Plate 362. Mean daily water temperature and discharge of the Missouri River at Fort Randall Dam (i.e., site FTRPP1) for 2009. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Fort Randall Dam.

Plate 363. Summary of water quality conditions monitored in the Niobrara River near Verdel, Nebraska (i.e., site GPTNFNIOR1) during 2008 and 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	13	1,991	1,710	753	3,560	-----	-----	-----
Water Temperature (°C)	0.1	13	18.1	21.7	0.4	27.2	29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0.1	12	9.7	8.8	7.5	14.7	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	12	103.2	104.3	91.2	125.4	-----	-----	-----
pH (S.U.)	0.1	12	8.4	8.4	7.5	8.9	6.5[1,5], 9.0[1,4]	0	0%
Specific Conductance (umho/cm)	1	13	284	280	222	364	2,000[4]	0	0%
Oxidation-Reduction Potential	1	13	360	346	305	491	-----	-----	-----
Alkalinity, Total (mg/l)	7	13	130	128	121	161	-----	0	0%
Carbon, Total Dissolved (mg/l)	0.05	7	2.8	3.4	1.4	3.5	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	13	4.3	3.5	1.8	11.6	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	13	21	20	6	38	-----	-----	-----
Chloride (mg/l)	1	13	3	3	2	6	-----	-----	-----
Chlorophyll *a* (ug/l)	1	7	48	35	1	111	-----	-----	-----
Color (S.U. - APHA)	1	7	13	15	6	23	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	13	206	204	168	262	-----	-----	-----
Hardness, Total (mg/l)	1	1	126	126	126	126	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	13	-----	0.03	n.d.	0.26	3.9 [1,4,7], 0.81 [1,6,7]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	13	1.1	1.2	0.4	2.1	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	13	0.73	0.60	0.03	1.80	10[2,4], 100[3,4]	0	0%
Nitrogen, Total (mg/l)	0.1	13	1.9	1.8	1.1	3.1	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	11	-----	0.04	n.d.	0.09	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	13	0.26	0.24	0.14	0.55	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	13	-----	0.04	n.d.	0.09	-----	-----	-----
Sulfate (mg/l)	1	13	21	20	15	30	-----	-----	-----
Suspended Solids, Total (mg/l)	4	13	198	150	66	560	-----	-----	-----
Turbidity (NTU)	1	12	135	84	40	491	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	1	-----	n.d.	n.d.	n.d.	750[8], 87[9]	0	0%
Antimony, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	88[8], 30[9], 6[10]	0	0%
Arsenic, Dissolved (ug/l)	1	1	4	4	4	4	340[8], 16.7[9,10], 10[10]	0	0%
Barium, Dissolved (ug/l)	5	1	111	111	111	111	2,000[2]	0	0%
Beryllium, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	130[8], 5.3[9], 4[10]	0	0%
Cadmium, Dissolved (ug/l)	0.2	1	-----	n.d.	n.d.	n.d.	7.4[8], 0.29[91], 5[10]	0, 1, 0	0%, 13%, 0%
Chromium, Dissolved (ug/l)	10	1	-----	n.d.	n.d.	n.d.	715[8], 93[9], 100[10]	0	0%
Copper, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	17[8], 11[9], 1,000[10]	0	0%
Iron, Dissolved (ug/l)	7	11	-----	20	n.d.	120	1,000[9]	0	0%
Lead, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	83[8], 3.2[9], 15[10]	0	0%
Manganese, Dissolved (ug/l)	2	11	-----	n.d.	n.d.	150	1,000[9]	0	0%
Mercury, Dissolved (ug/l)	0.05	1	-----	n.d.	n.d.	n.d.	1.4[8]	0	0%
Mercury, Total (ug/l)	0.05	1	-----	n.d.	n.d.	n.d.	0.77[9], 2[10]	0	0%
Nickel, Dissolved (ug/l)	10	1	-----	n.d.	n.d.	n.d.	569[8], 63[9], 100[10]	0	0%
Selenium, Total (ug/l)	1	1	3	3	3	3	20[3,8], 5[9], 50[10]	0	0%
Silver, Dissolved (ug/l)	1	1	-----	n.d.	n.d.	n.d.	5.1[8], 100[10]	0	0%
Thallium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	1,400[8], 6.3[9], 2[10]	0	0%
Zinc, Dissolved (ug/l)	5	1	-----	n.d.	n.d.	n.d.	143[10,11], 5,000[12]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	2	-----	n.d.	n.d.	n.d.	-----	-----	-----
Atrazine, Total (ug/l)[D]	0.05	2	-----	0.15	n.d.	0.30	330[8], 12[9], 3[10]	0	0%
Metolachlor, Total (ug/l)[D]	0.05	2	-----	n.d.	n.d.	n.d.	390[8], 100[9]	0	0%
THM Formation Potential, Total	4	7	156	152	98	220	-----	-----	-----

n.d. = Not detected.

[A] Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- [2] South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- [3] Criteria for the protection of domestic water supply waters.
- [4] Criteria for the protection of agricultural water supply waters.
- [5] Criteria for the protection of commerce and industry waters.
- [6] Daily maximum criterion (monitoring results directly comparable to criterion).
- [7] Daily minimum criterion (monitoring results directly comparable to criterion).
- [8] 30-day average criterion (monitoring results not directly comparable to criterion).
- [9] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- [10] Acute (CMC) criterion for the protection of freshwater aquatic life.
- [11] Chronic (CCC) criterion for the protection of freshwater aquatic life.

Note: Some of Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] Immunoassay analysis.

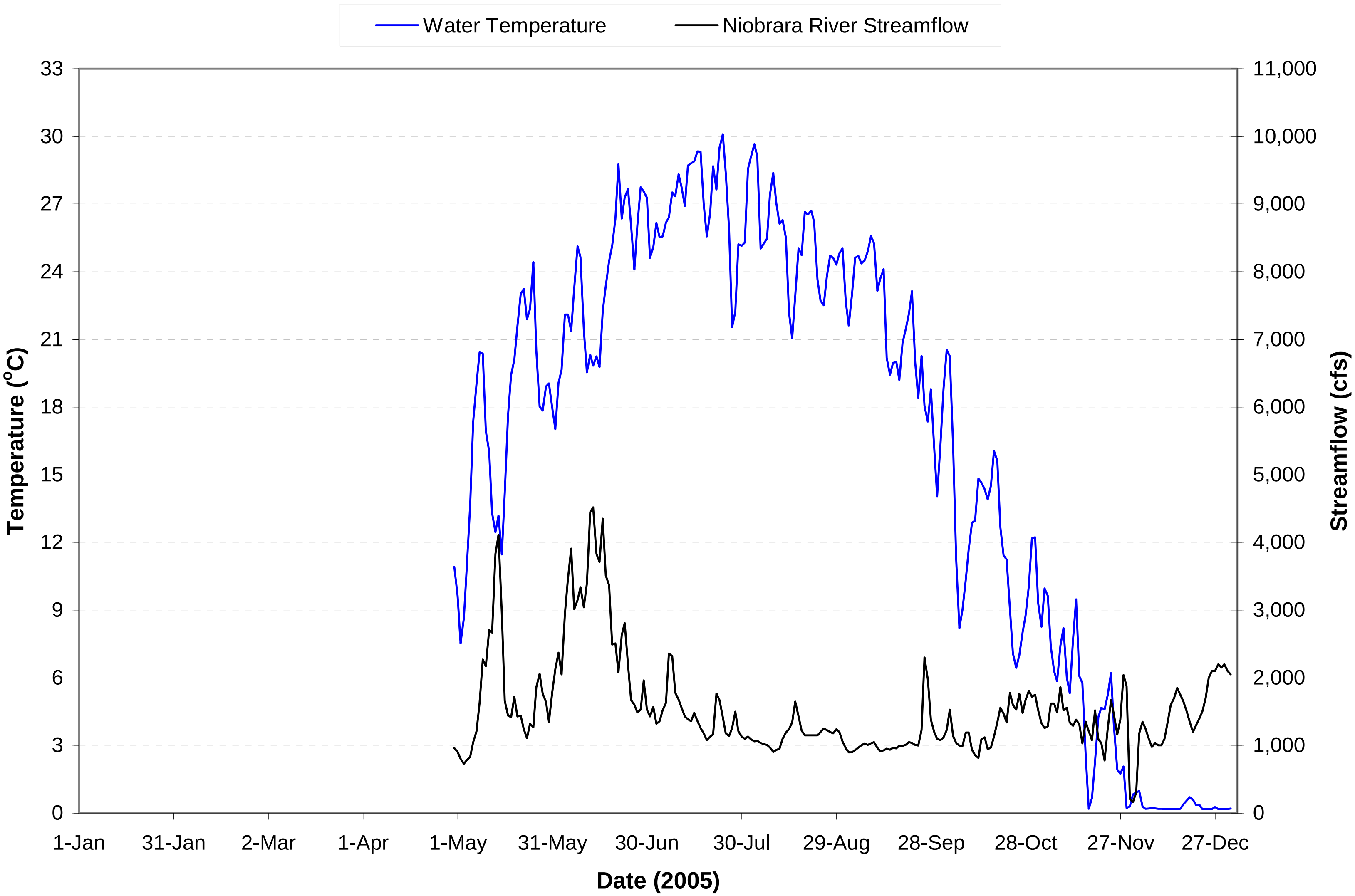


Plate 364. Mean daily water temperature and streamflow of the Niobrara River near Verdel, Nebraska (i.e., site USGS 06465500) for 2005.

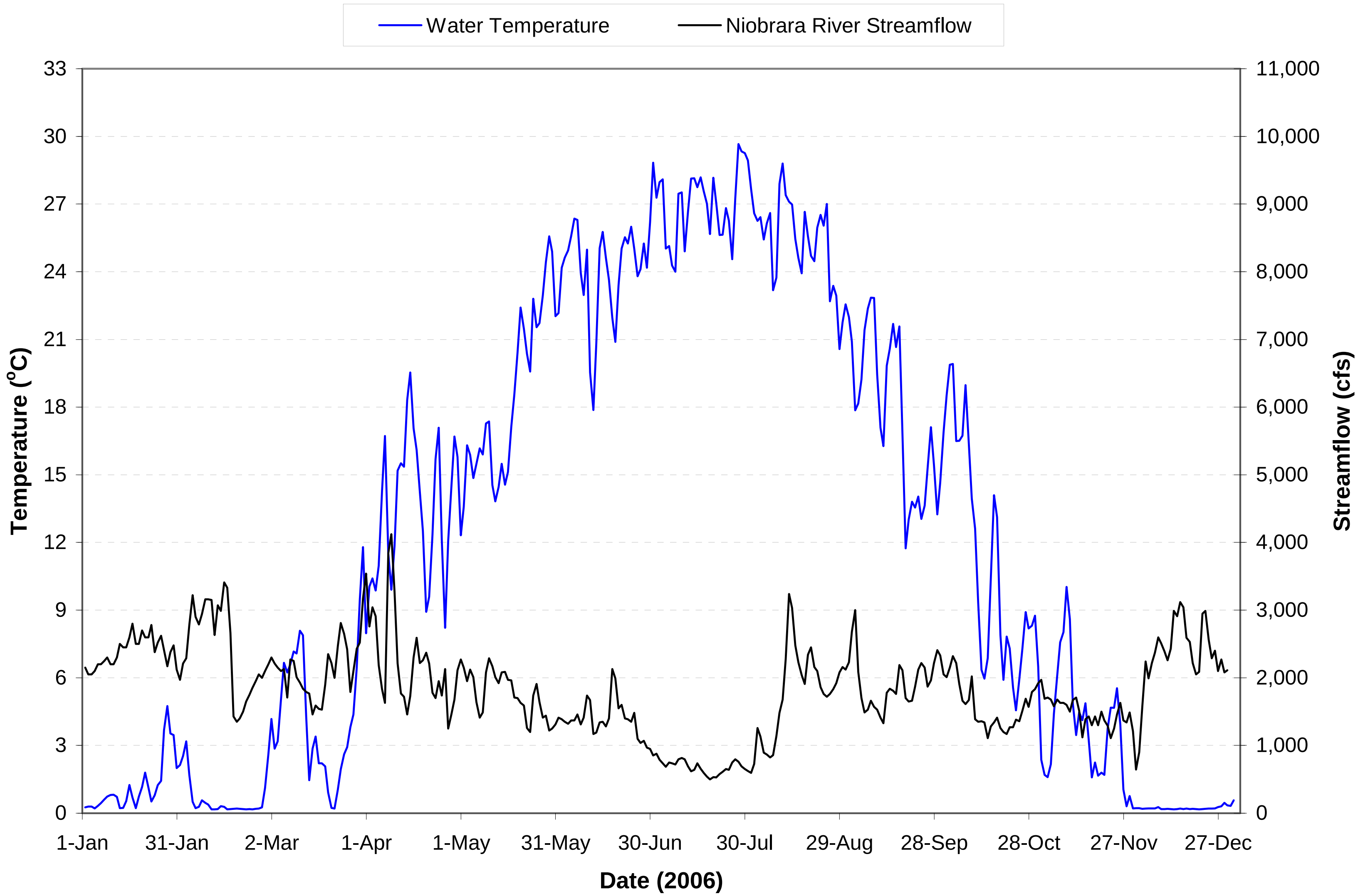


Plate 365. Mean daily water temperature and streamflow of the Niobrara River near Verdel, Nebraska (i.e., site USGS 06465500) for 2006.

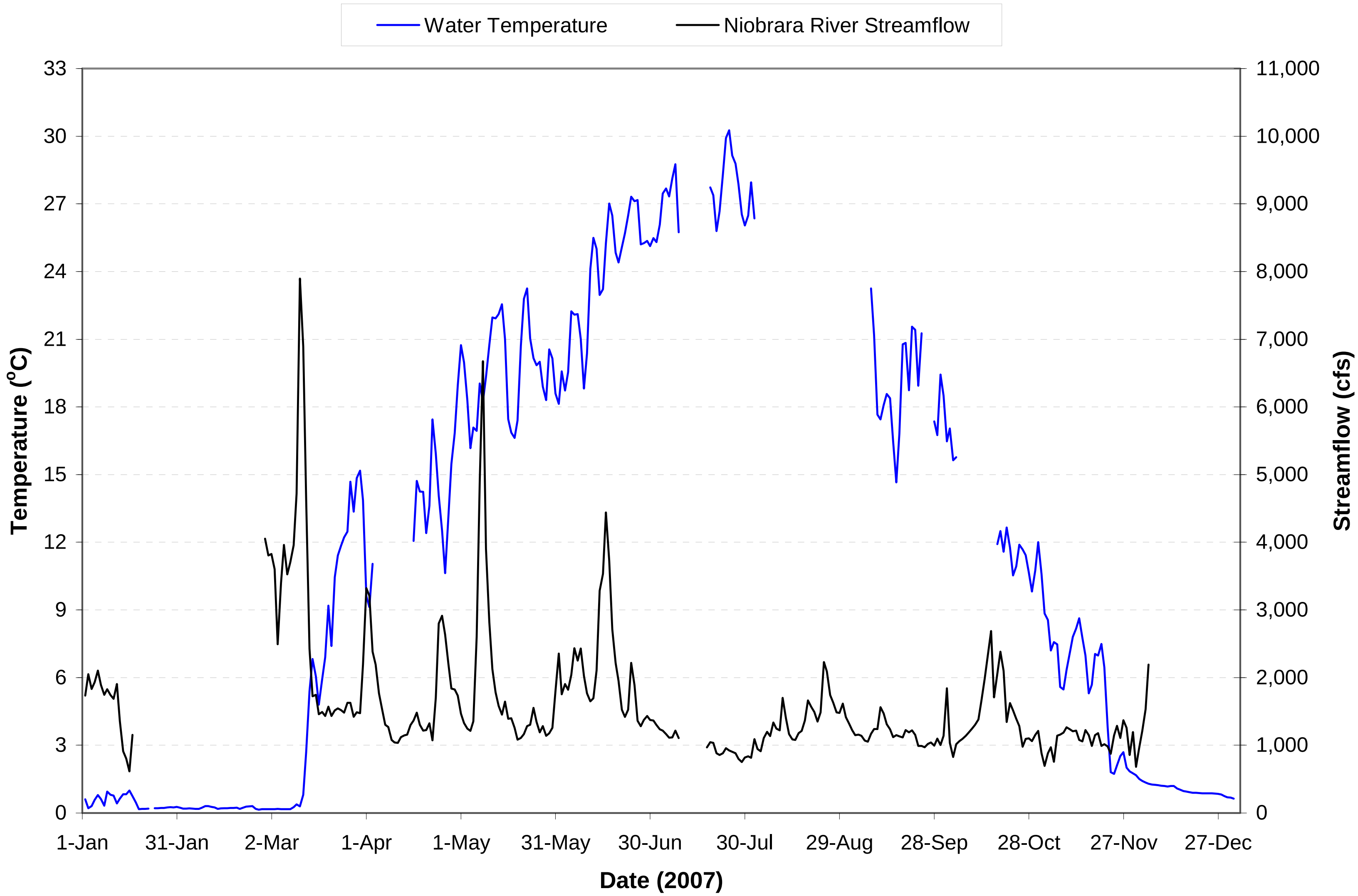


Plate 366. Mean daily water temperature and streamflow of the Niobrara River near Verdel, Nebraska (i.e., site USGS 06465500) for 2007.

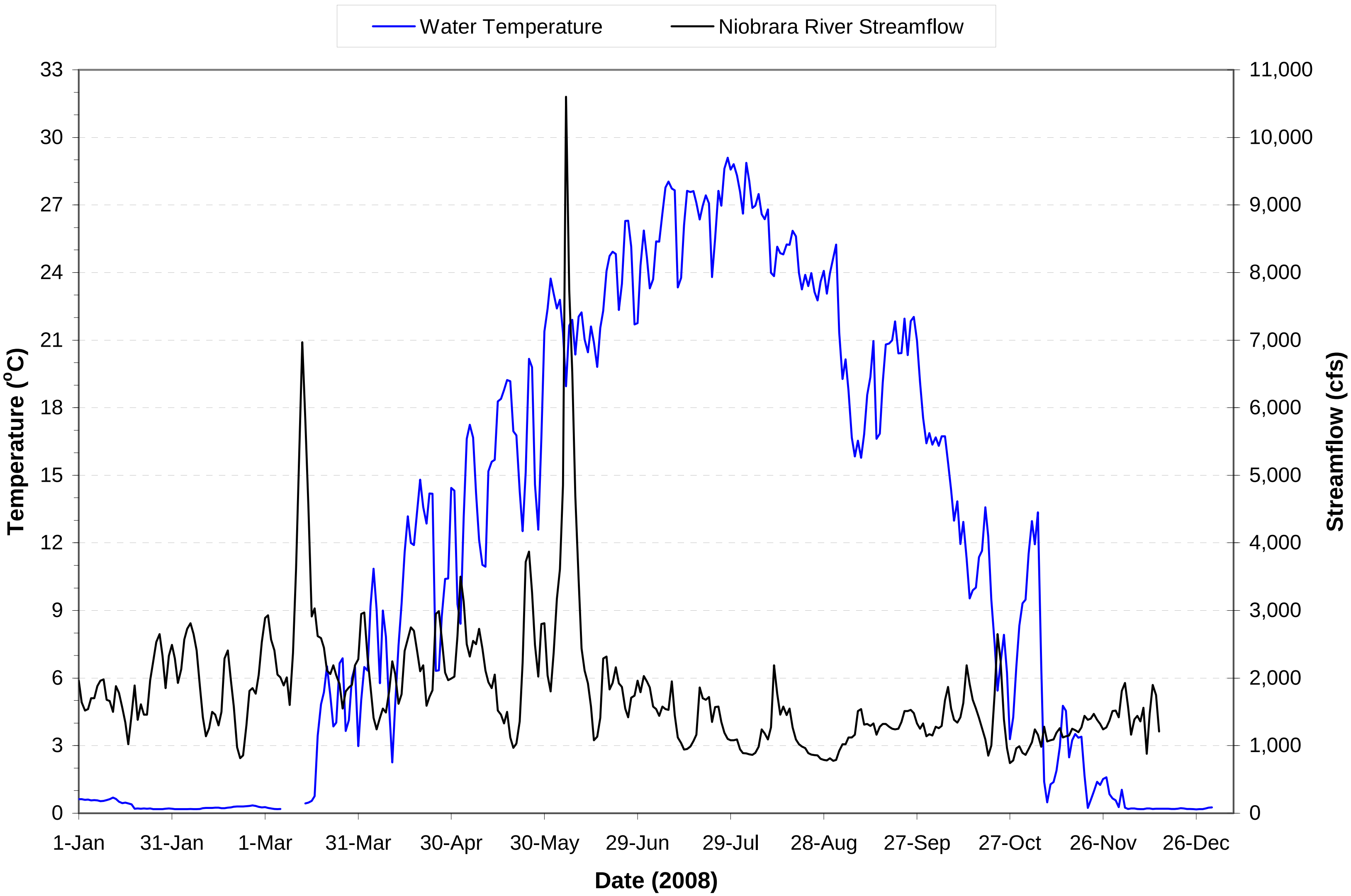


Plate 367. Mean daily water temperature and streamflow of the Niobrara River near Verdel, Nebraska (i.e., site USGS 06465500) for 2008.

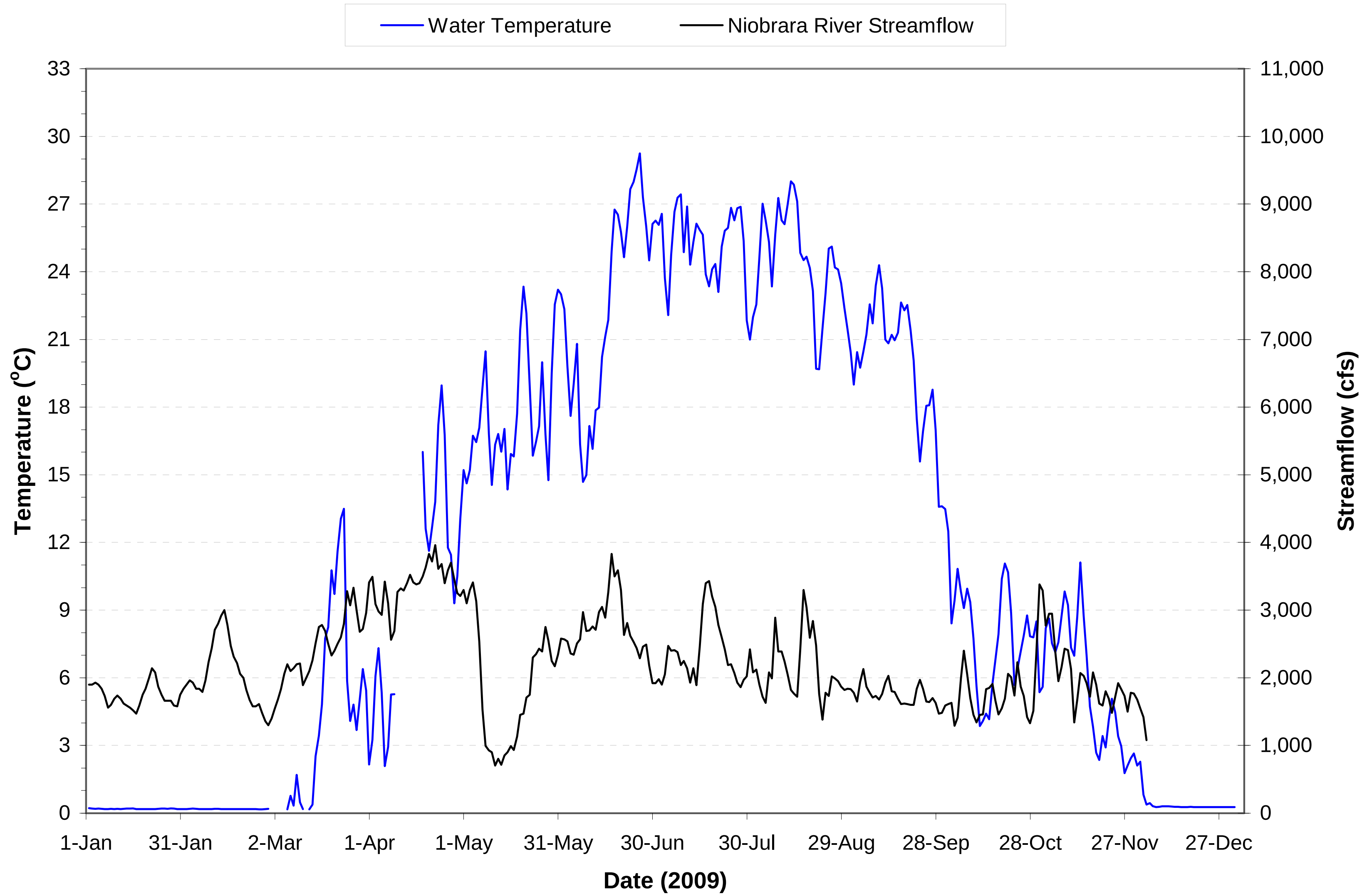


Plate 368. Mean daily water temperature and streamflow of the Niobrara River near Verdel, Nebraska (i.e., site USGS 06465500) for 2009.

Plate 369. Summary of water quality conditions monitored in the Missouri River near Niobrara, Nebraska (i.e., site GPTNFMORR1) at RM841 during 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	8	28,382	27,046	19,230	41,857	-----	-----	-----
Water Temperature (°C)	0.1	8	11.5	11.0	1.1	24.9	27[1,2,6], 29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0.1	8	10.4	10.4	7.0	13.4	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	8	95.4	95.0	85.8	104.2	-----	-----	-----
pH (S.U.)	0.1	8	8.1	8.2	7.5	8.5	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Specific Conductance (umho/cm)	1	8	574	602	420	653	2,000[4]	0	0%
Oxidation-Reduction Potential	1	7	348	352	303	391	-----	-----	-----
Alkalinity, Total (mg/l)	7	8	146	144	138	156	-----	0	0%
Carbon, Total Dissolved (mg/l)	0.05	7	2.7	2.7	2.0	3.4	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	8	3.2	3.0	2.0	4.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	8	12	12	7	24	-----	-----	-----
Chloride (mg/l)	1	8	10	10	8	12	438[3,6], 250[3,8]	0	0%
Chlorophyll *a* (ug/l)	1	7	16	14	3	42			
Color (S.U. - APHA)	1	7	9	9	5	14	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	8	396	400	314	490	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	0	0%
Hardness, Total (mg/l)	1	3	185	183	182	190	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	8	-----	0.06	n.d.	0.09	5.7[1,6,9], 1.7 [1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	8	0.7	0.6	0.2	1.3	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	8	-----	0.40	n.d.	1.00	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	8	1.2	1.1	0.6	2.2	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	5	-----	0.02	n.d.	0.05	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	8	0.08	0.10	n.d.	0.13	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	8	-----	n.d.	n.d.	0.04	-----	-----	-----
Suspended Solids, Total (mg/l)	4	8	45	44	4	78	158[1,6], 90[1,8]	0	0%
Turbidity (NTU)	1	8	59	27	n.d.	213	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	3	-----	n.d.	n.d.	n.d.	750[10], 87[11]	0	0%
Antimony, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	88[10], 30[11]	0	0%
Arsenic, Dissolved (ug/l)	1	3	3	3	2	3	340[10], 16.7[11]	0	0%
Barium, Dissolved (ug/l)	5	3	66	68	54	75	-----	-----	-----
Beryllium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	130[10], 5.3[11]	0	0%
Cadmium, Dissolved (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	3.6[10], 0.37[11]	0	0%
Chromium, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	935[10], 122[11]	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	24[10], 15[11]	0	0%
Iron, Dissolved (ug/l)	7	3	10	10	10	10	1,000[11]	0	0%
Lead, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	124[10], 4.8[11]	0	0%
Manganese, Dissolved (ug/l)	2	3	-----	10	n.d.	40	1,000[11]	0	0%
Mercury, Dissolved (ug/l)	0.05	2	-----	n.d.	n.d.	n.d.	1.4[10]	0	0%
Mercury, Total (ug/l)	0.05	2	-----	n.d.	n.d.	n.d.	0.77[11], 2[3]	0	0%
Nickel, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	781[10], 87[11]	0	0%
Selenium, Total (ug/l)	1	3	3	3	2	3	20[4,10], 5[11], 50[3]	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	9.1[10], 100[3]	0	0%
Thallium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	1,400[10], 6.3[11], 2[3]	0	0%
Zinc, Dissolved (ug/l)	5	3	-----	n.d.	n.d.	n.d.	196[10,11], 5,000[3]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Atrazine, Total (ug/l)[D]	0.05	6	-----	n.d.	n.d.	0.10.	330[10], 12[11], 3[3]	0	0%
Metolachlor, Total (ug/l)[D]	0.05	6	-----	n.d.	n.d.	n.d.	390[10], 100[11]	0	0%
Pesticide Scan (ug/l)[E]	0.05	1	-----	n.d.	n.d.	n.d.	-----	-----	-----
THM Formation Potential, Total	4	7	170	164	134	209	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
(2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
(3) Criteria for the protection of domestic water supply waters.
(4) Criteria for the protection of agricultural water supply waters.
(5) Criteria for the protection of commerce and industry waters.
(6) Daily maximum criterion (monitoring results directly comparable to criterion).
(7) Daily minimum criterion (monitoring results directly comparable to criterion).
(8) 30-day average criterion (monitoring results not directly comparable to criterion).
(9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(10) Acute (CMC) criterion for the protection of freshwater aquatic life.
(11) Chronic (CCC) criterion for the protection of freshwater aquatic life.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

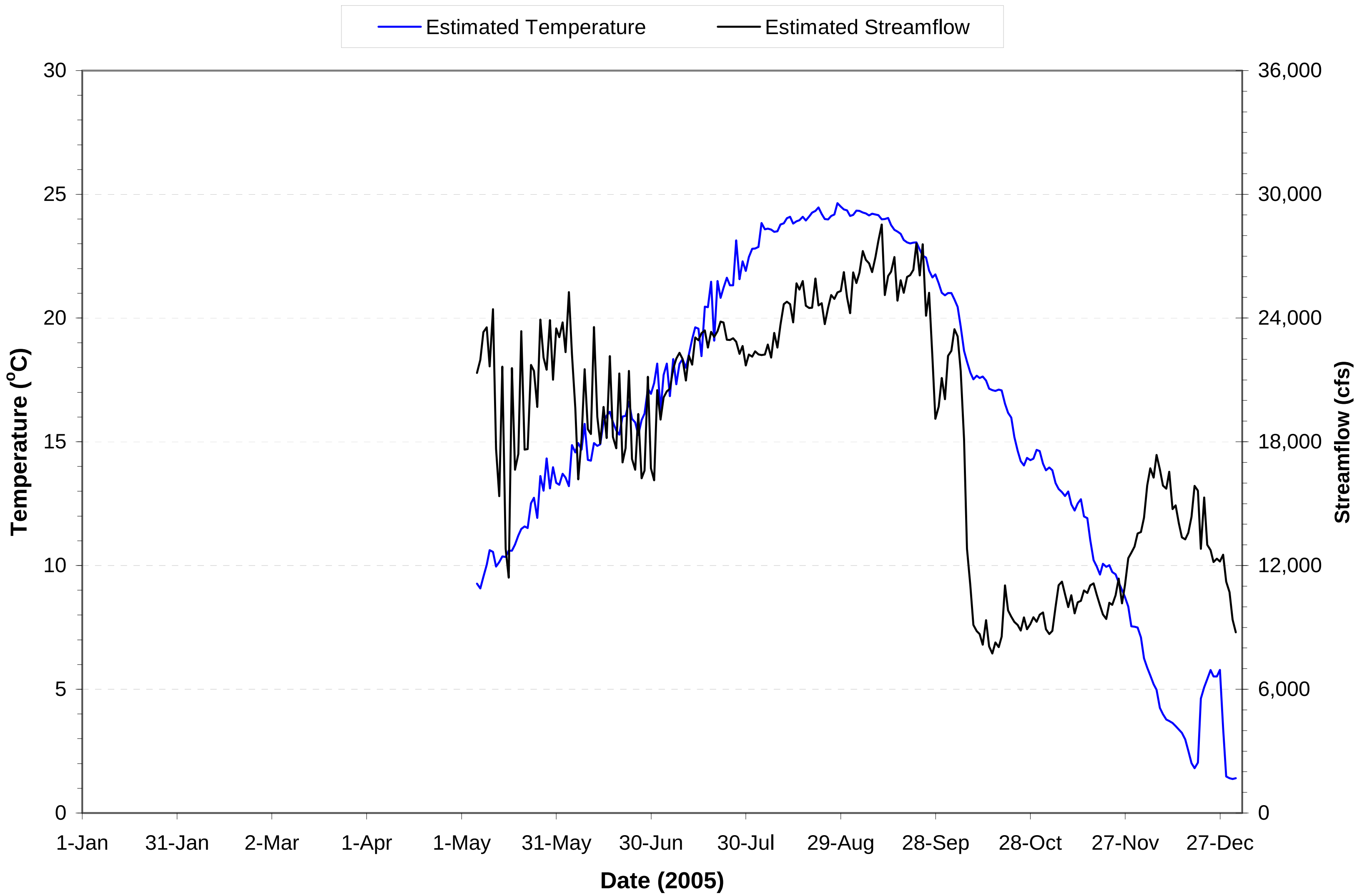


Plate 370. Mean daily water temperature and streamflow estimated for the Missouri River inflow to Lewis and Clark Lake for 2005. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, Nebraska at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites.

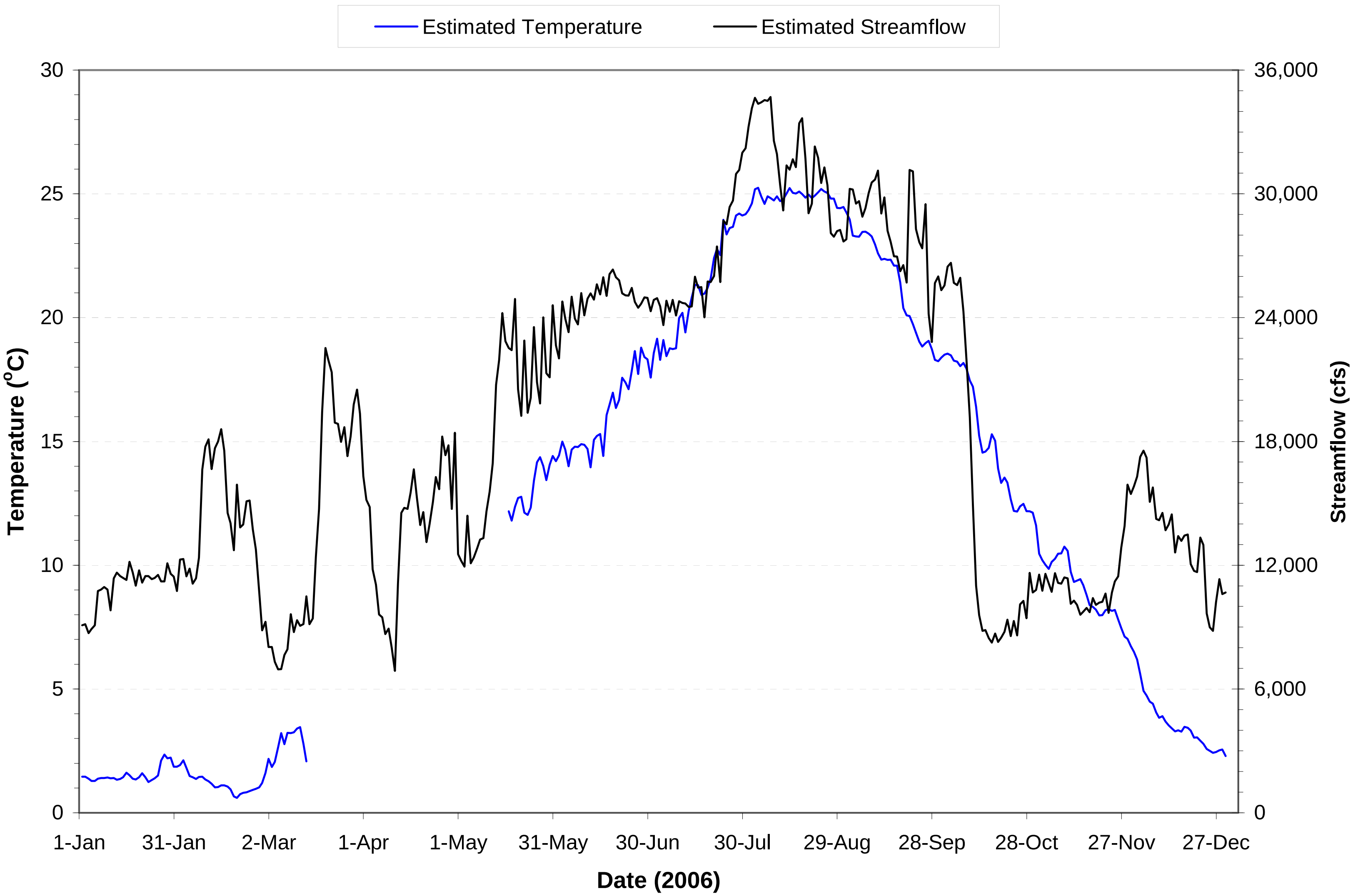


Plate 371. Mean daily water temperature and streamflow estimated for the Missouri River inflow to Lewis and Clark Lake for 2006. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, Nebraska at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites. (Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

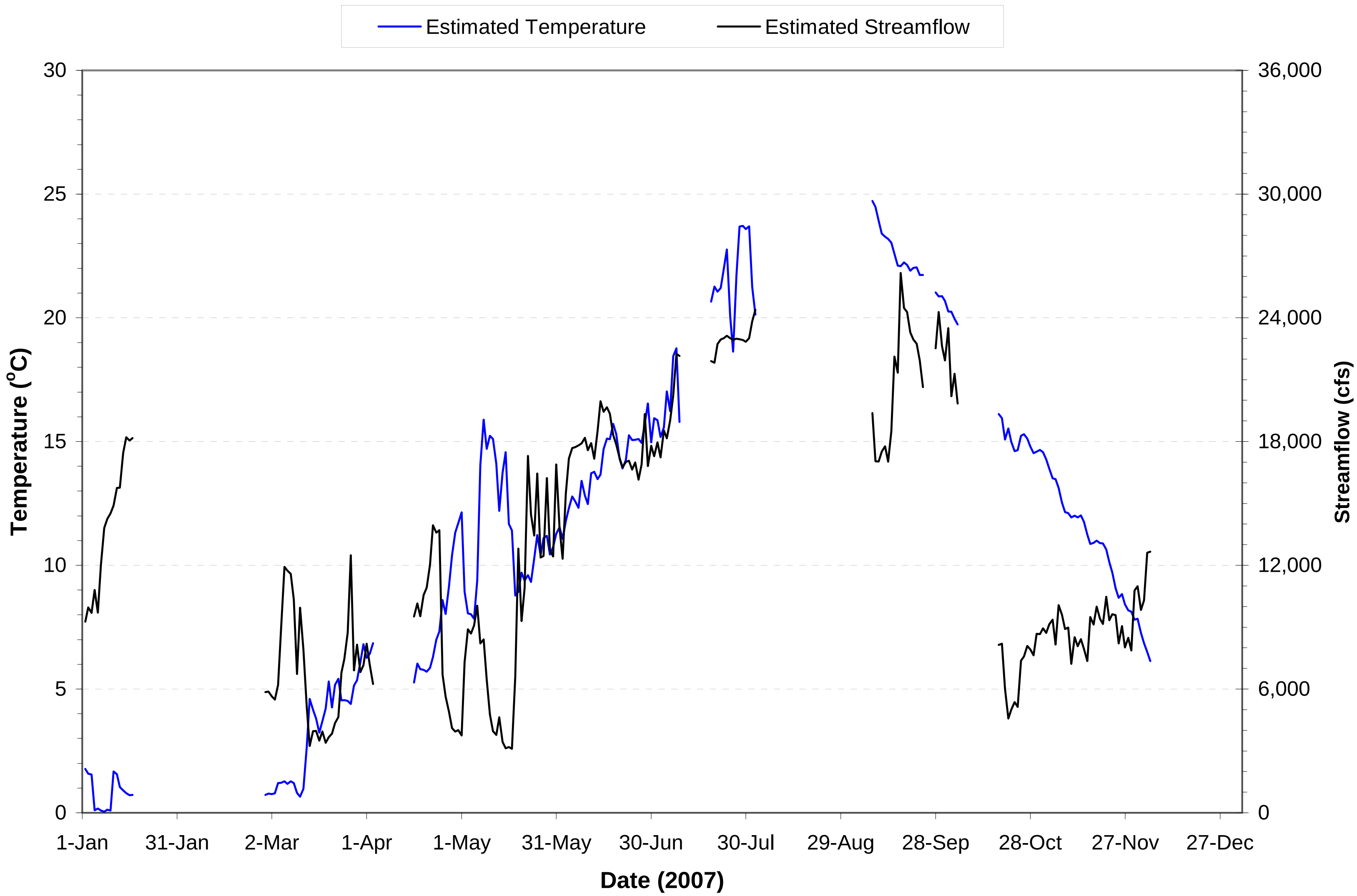


Plate 372. Mean daily water temperature and streamflow estimated for the Missouri River inflow to Lewis and Clark Lake for 2007. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, Nebraska at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites. (Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

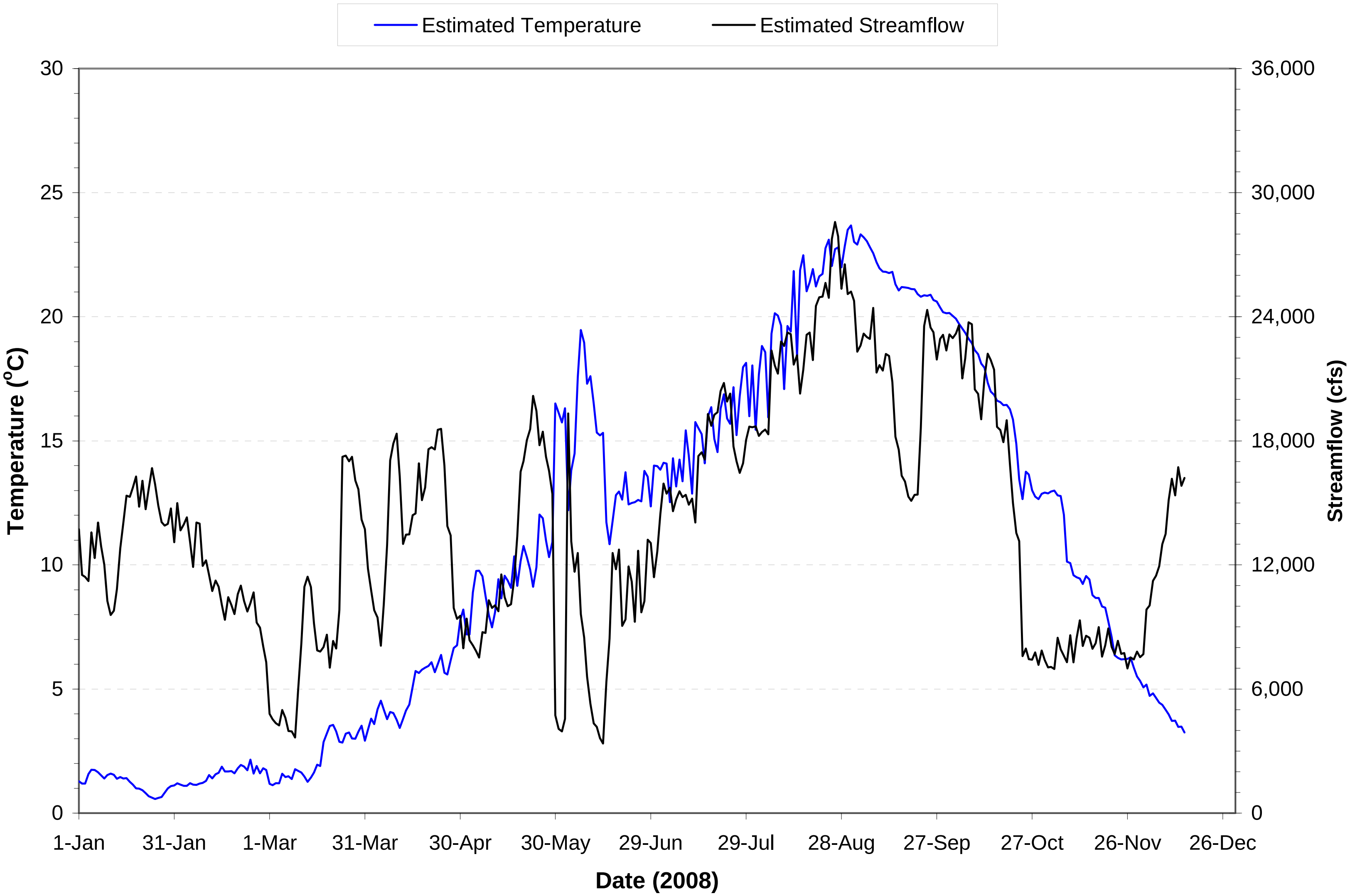


Plate 373. Mean daily water temperature and streamflow estimated for the Missouri River inflow to Lewis and Clark Lake for 2008. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, Nebraska at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites.

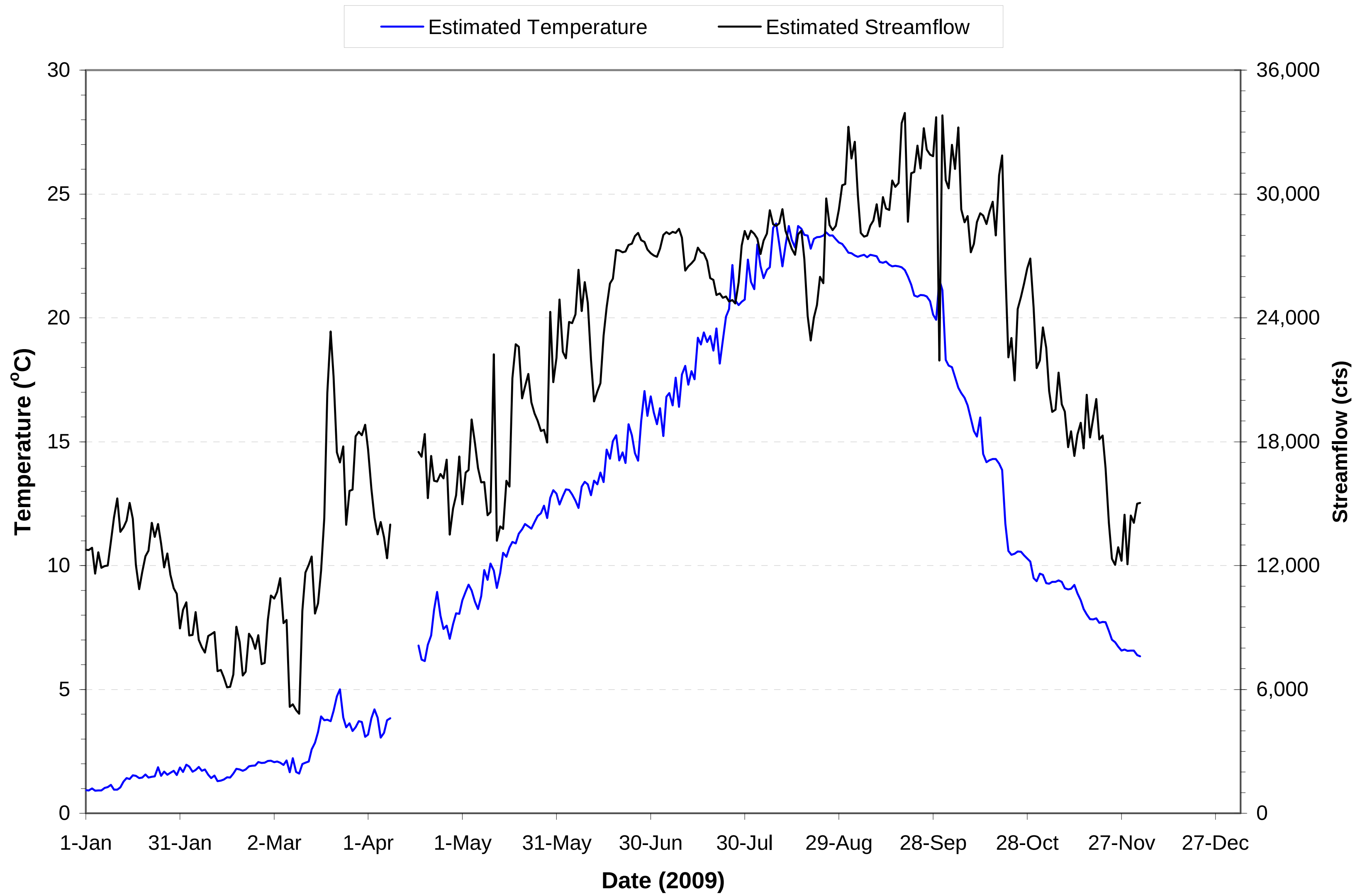


Plate 374. Mean daily water temperature and streamflow estimated for the Missouri River inflow to Lewis and Clark Lake for 2009. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, Nebraska at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites.

Plate 375. Summary of water quality conditions monitored on water discharged through Gavins Point Dam (i.e., site GPTPP1) during the 5-year period of 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Dam Discharge (cfs)	1	50	17,218	17,009	8,000	29,500	-----	-----	-----
Water Temperature (°C)	0.1	49	13.9	14.3	0.7	26.3	27[1,2,6], 29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0.1	48	9.8	9.6	2.6	13.9	5[1,7]	1	2%
Dissolved Oxygen (% Sat.)	0.1	48	96.0	97.2	20.1	121.6	-----	-----	-----
pH (S.U.)	0.1	47	8.3	8.3	7.1	8.9	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Specific Conductance (umho/cm)	1	48	668	691	463	762	2,000[4]	-----	-----
Oxidation-Reduction Potential (mV)	1	34	363	366	237	503	-----	-----	-----
Turbidity (NTU)	1	31	39	13	n.d.	824	-----	-----	-----
Alkalinity, Total (mg/l)	7	50	159	159	129	197	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	49	3.5	3.0	1.21	13.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	41	11	10	n.d.	35	-----	-----	-----
Chloride, Dissolved (mg/l)	1	39	11	11	8	19	438[3,6], 250[3,8]	0	0%
Dissolved Solids, Total (mg/l)	5	50	447	452	310	542	1,750[2,4], 1,000[2,7], 3,500[3,4], 2,000[3,6]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	50	-----	0.03	n.d.	0.44	4.7[1,6,9], 1.4[1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	50	0.6	0.5	n.d.	1.8	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	50	-----	0.04	n.d.	0.60	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	50	0.7	0.6	n.d.	2.3			
Phosphorus, Dissolved (mg/l)	0.02	38	-----	0.02	n.d.	0.19	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	50	0.06	0.05	n.d.	0.38	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	50	-----	n.d.	n.d.	0.19	-----	-----	-----
Sulfate (mg/l)	1	50	190	190	107	230	875[3,6], 500[3,8]	0	0%
Suspended Solids, Total (mg/l)	4	50	12	10	n.d.	45	158[1,6], 90[1,8]	0	0%

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

Plate 376. Summary of annual metals and pesticide levels monitored on water discharged through Gavins Point Dam (i.e., site GPTPP1) during the 5-year period of 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	3	-----	n.d.	n.d.	26	750[1], 87[2], 200[3]	0	0%
Aluminum, Total (ug/l)	25	3	245	235	200	300	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	3	-----	0.6	n.d.	0.8	88[1], 30[2], 6[3]	0	0%
Antimony, Total (ug/l)	0.5	3	-----	0.6	n.d.	1.0	5.6[4]	0	0%
Arsenic, Dissolved (ug/l)	1	7	-----	n.d.	n.d.	3	340[1], 16.7[2]	0	0%
Arsenic, Total (ug/l)	1	3	2.3	2	2	3	10[3], 0.018[4]	0, b.d.	0%, b.d.
Barium, Dissolved (ug/l)	5	3	46	46	44	49	-----	-----	-----
Barium, Total (ug/l)	5	3	49	50	47	50	2,000[3]	0	0%
Beryllium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	130[1], 5.3[2]	0	0%
Beryllium, Total (ug/l)	2	3	-----	n.d.	n.d.	n.d.	4[4]	0	0%
Cadmium, Dissolved (ug/l)	0.2	7	-----	n.d.	n.d.	n.d.	4.3[1], 0.43[2]	0	0%
Cadmium, Total (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	5[3,4]	0	0%
Chromium, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	n.d.	1,087[1], 141[2]	0	0%
Chromium, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	100[3]	-----	-----
Copper, Dissolved (ug/l)	2	7	-----	8	n.d.	15	28[1], 18[2],	0	0%
Copper, Total (ug/l)	2	3	-----	n.d.	n.d.	140	1,300[3,4]	0	0%
Hardness, Total (mg/l)	1	4	222	220	208	238	-----	-----	-----
Iron, Dissolved (ug/l)	40	24	-----	n.d.	n.d.	246	1,000[2]	0	0%
Iron, Total (ug/l)	40	24	385	308	70	1,620	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	151[1], 5.9[2]	0	0%
Lead, Total (ug/l)	0.5	3	-----	n.d.	n.d.	0.6	-----	-----	-----
Manganese, Dissolved (ug/l)	2	24	10	4	n.d.	70	1,000[2]	0	0%
Manganese, Total (ug/l)	2	24	69	51	6	290	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	8	-----	n.d.	n.d.	n.d.	1.4[1]	0	0%
Mercury, Total (ug/l)	0.05	8	-----	n.d.	n.d.	n.d.	0.77[2], 0.05[3], 2[3]	0	0%
Nickel, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	n.d.	912[1], 101[2]	0	0%
Nickel, Total (ug/l)	10	3	-----	n.d.	n.d.	n.d.	610[4]	0	0%
Selenium, Total (ug/l)	1	3	-----	2	n.d.	3	20[1], 5[2], 50[3], 170[4]	0	0%
Silver, Dissolved (ug/l)	1	7	-----	n.d.	n.d.	n.d.	13[1]	0	0%
Silver, Total (ug/l)	1	3	-----	n.d.	n.d.	n.d.	10[3]	0	0%
Thallium, Dissolved (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	1,400[1], 6.3[2], 2[3], 0.24[3]	0	0%
Thallium, Total (ug/l)	0.5	3	-----	n.d.	n.d.	n.d.	0.24[3]	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	13	229[1,2]	0	0%
Zinc, Total (ug/l)	10	3	-----	n.d.	n.d.	33	5,000[4], 7,400[4]	0	0%
Pesticide Scan (ug/l)[D]	0.05	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected, b.d. = Criterion below detection limit.

[A] Results for iron (dissolved and total) and manganese (dissolved and total) include some monthly samples.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Acute (CMC) criterion for the protection of freshwater aquatic life.
- [2] Chronic (CCC) criterion for the protection of freshwater aquatic life.
- [3] Criterion for the protection of domestic water supply waters.
- [4] Criterion for the protection of human health.

Note: Some of South Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

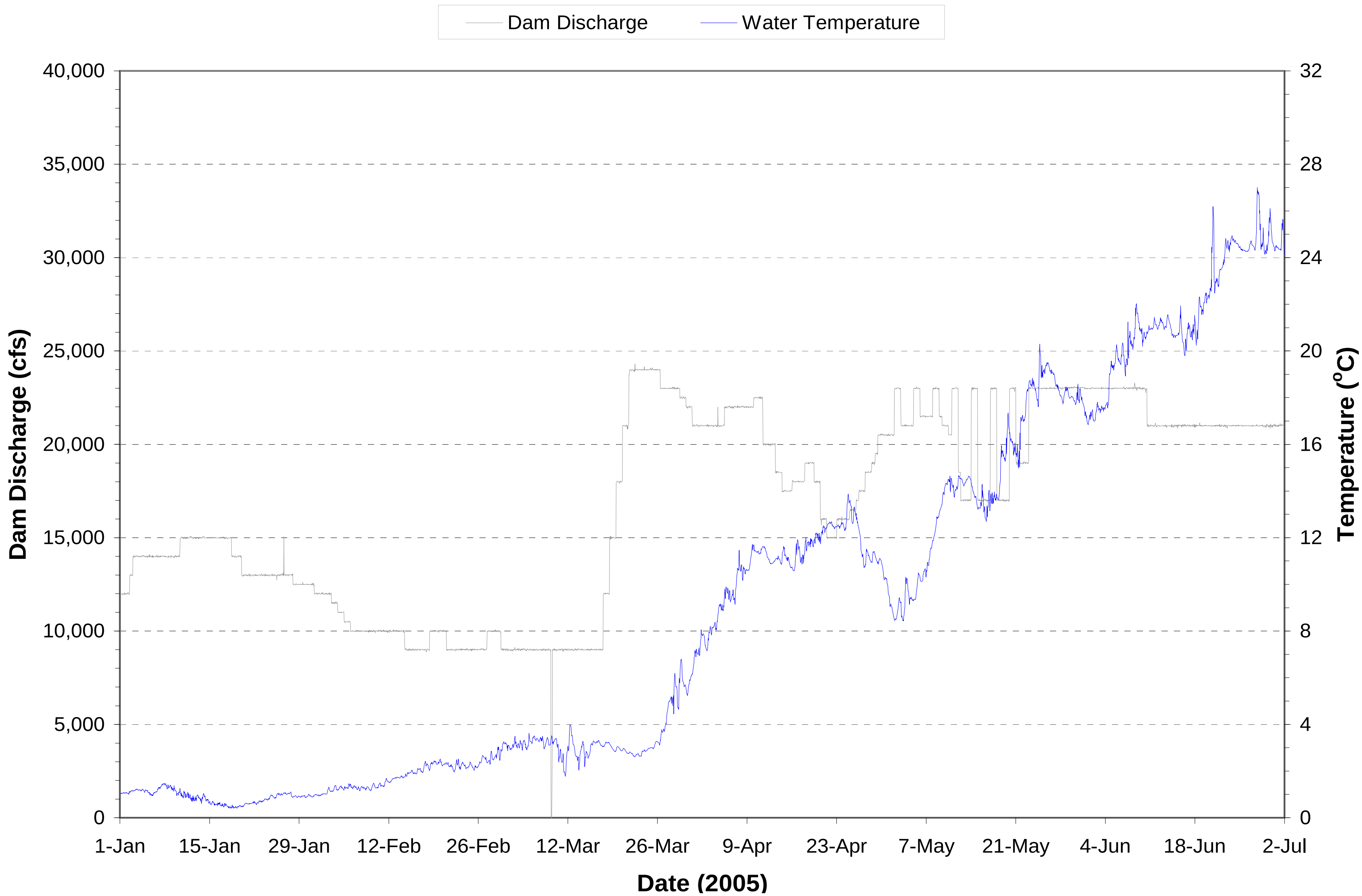


Plate 377. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2005.

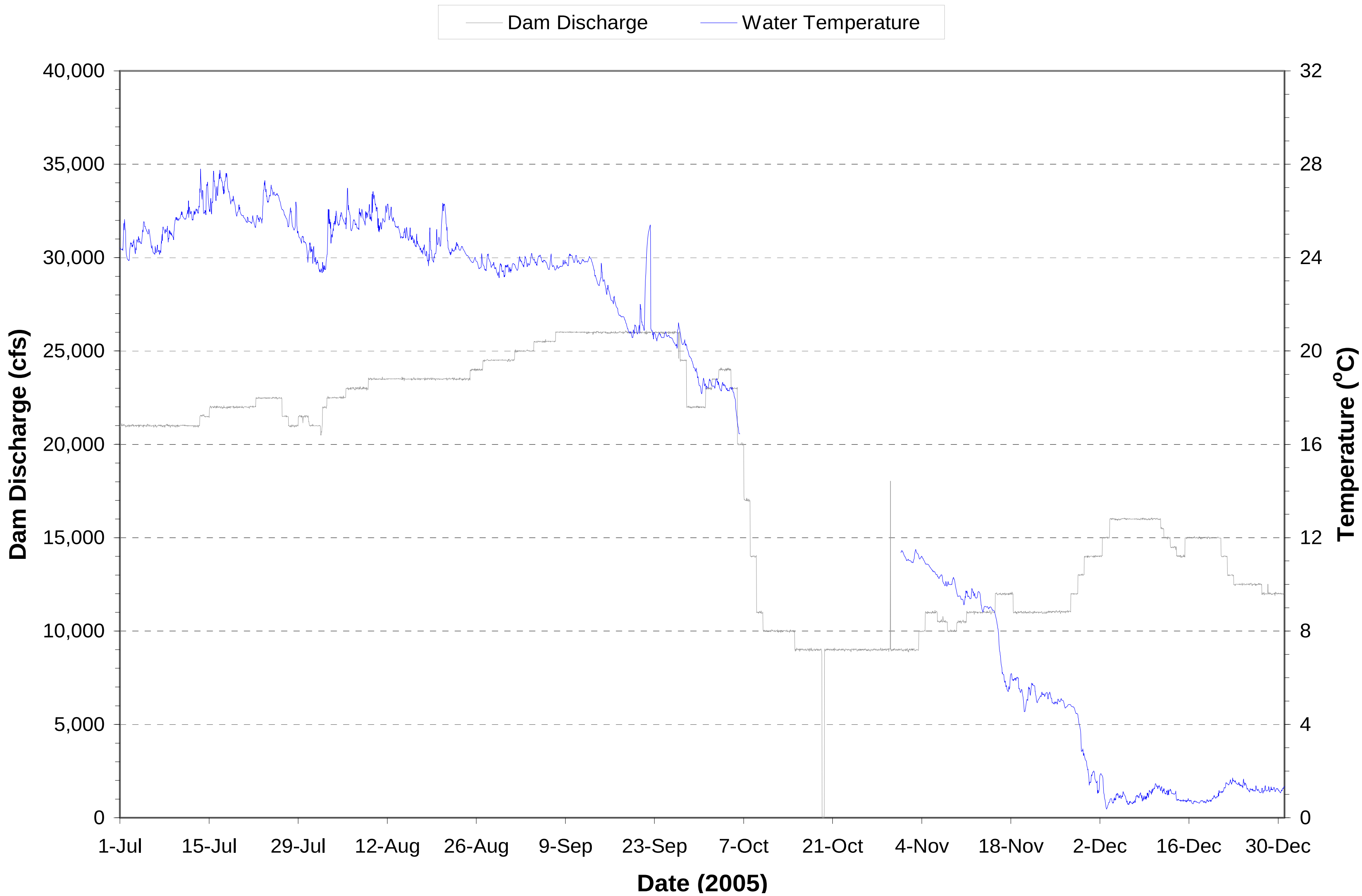


Plate 378. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2005.
Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.

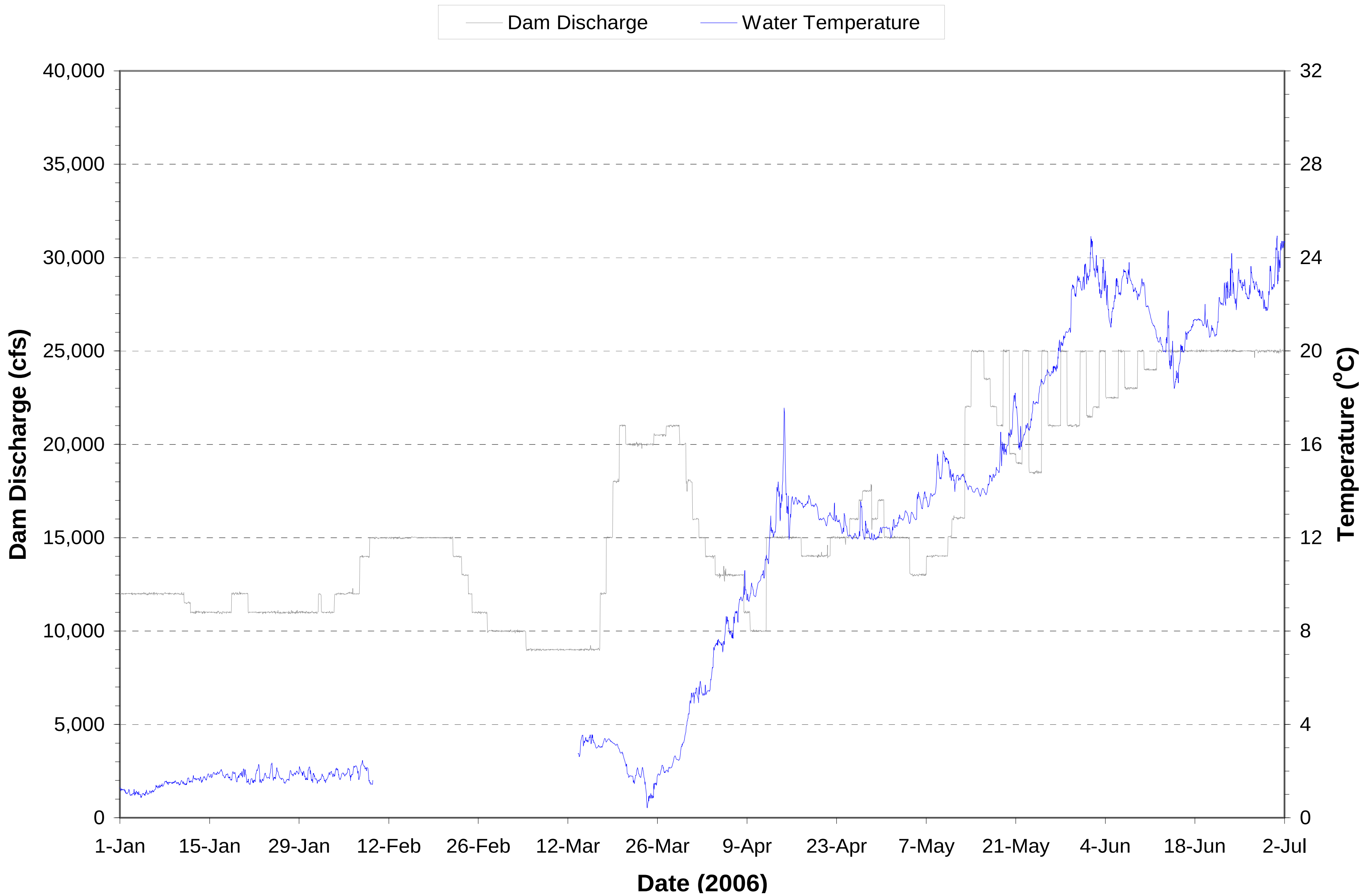


Plate 379. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2006.
Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.

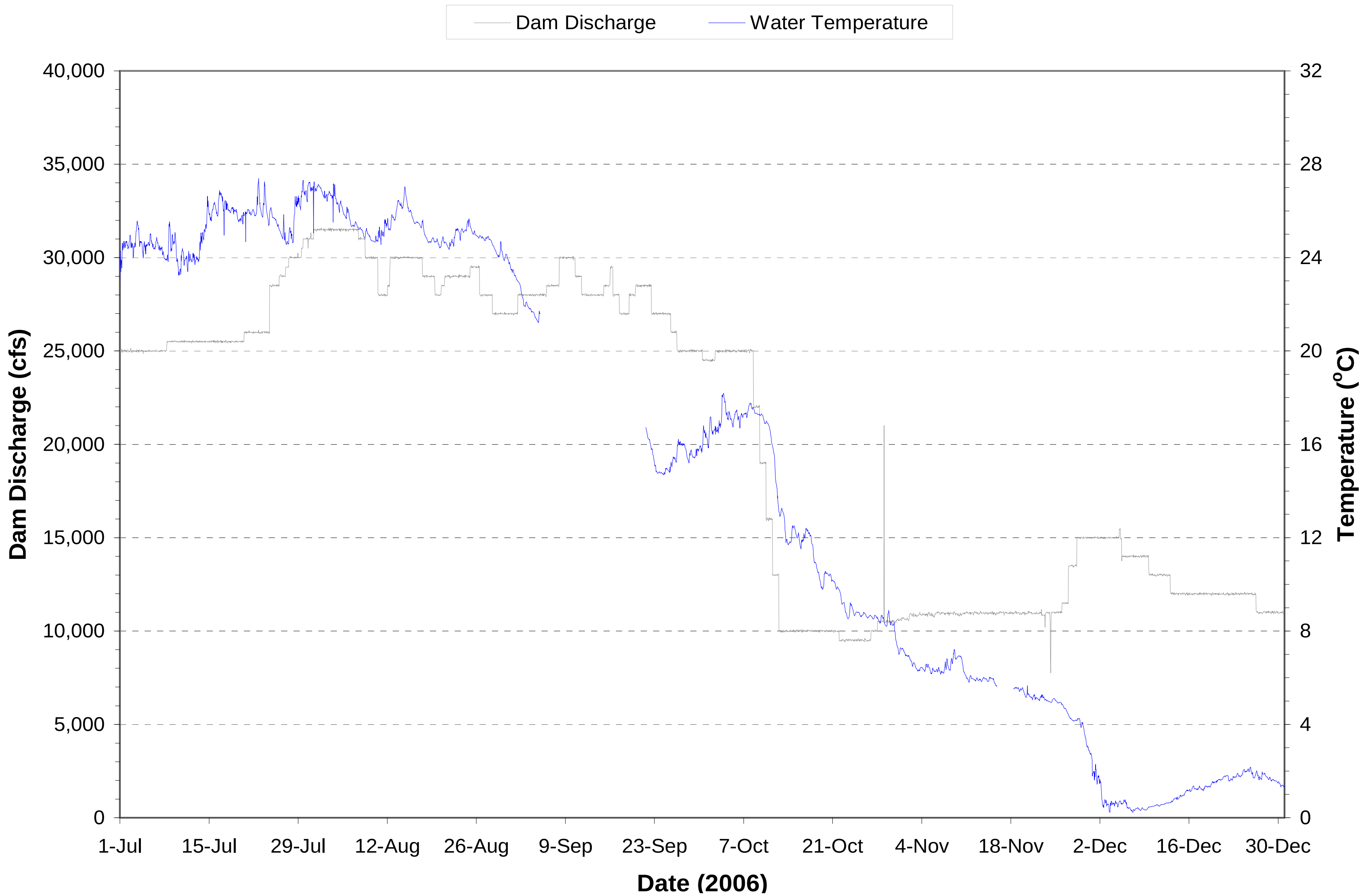


Plate 380. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2006.
Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.

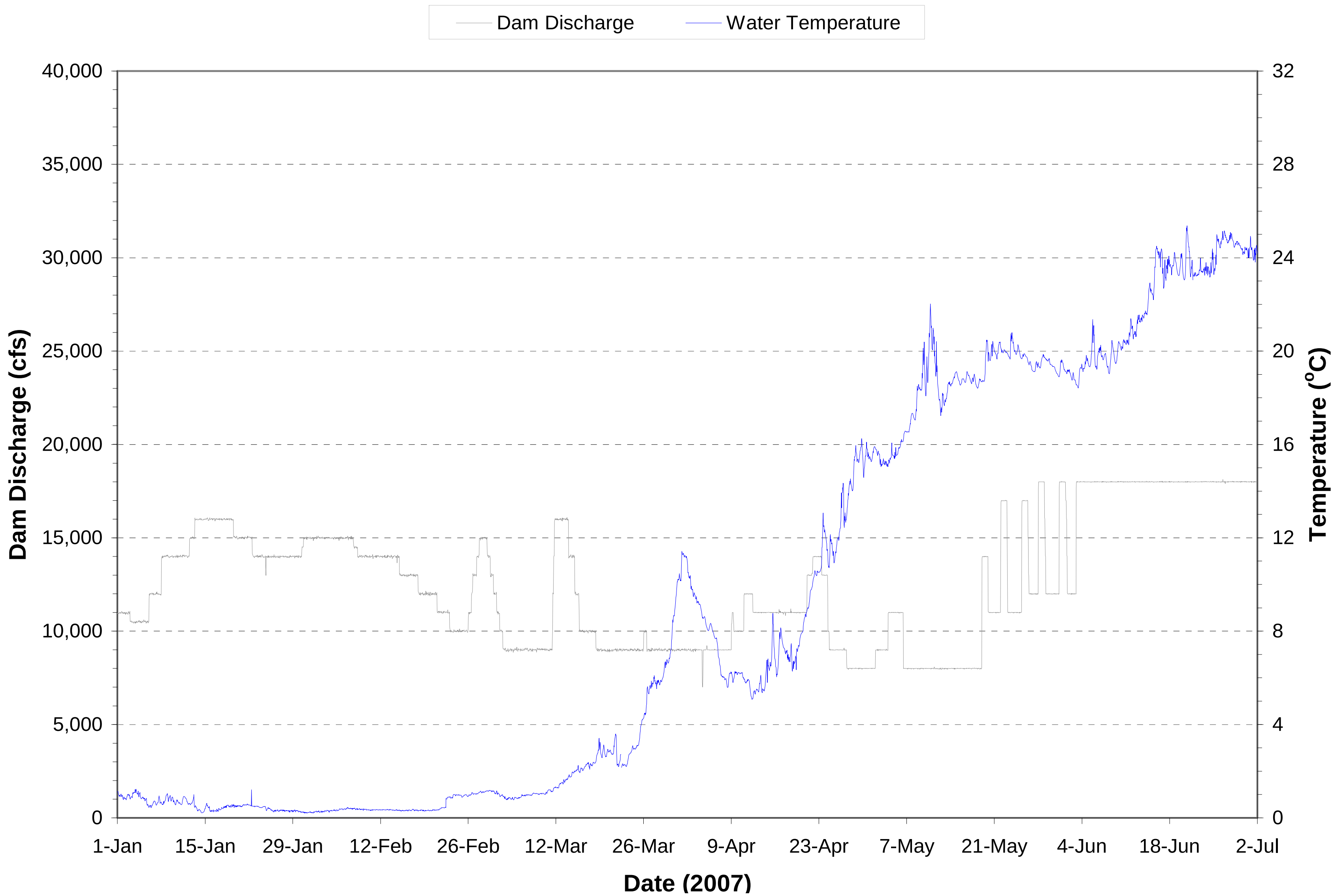


Plate 381. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2007.

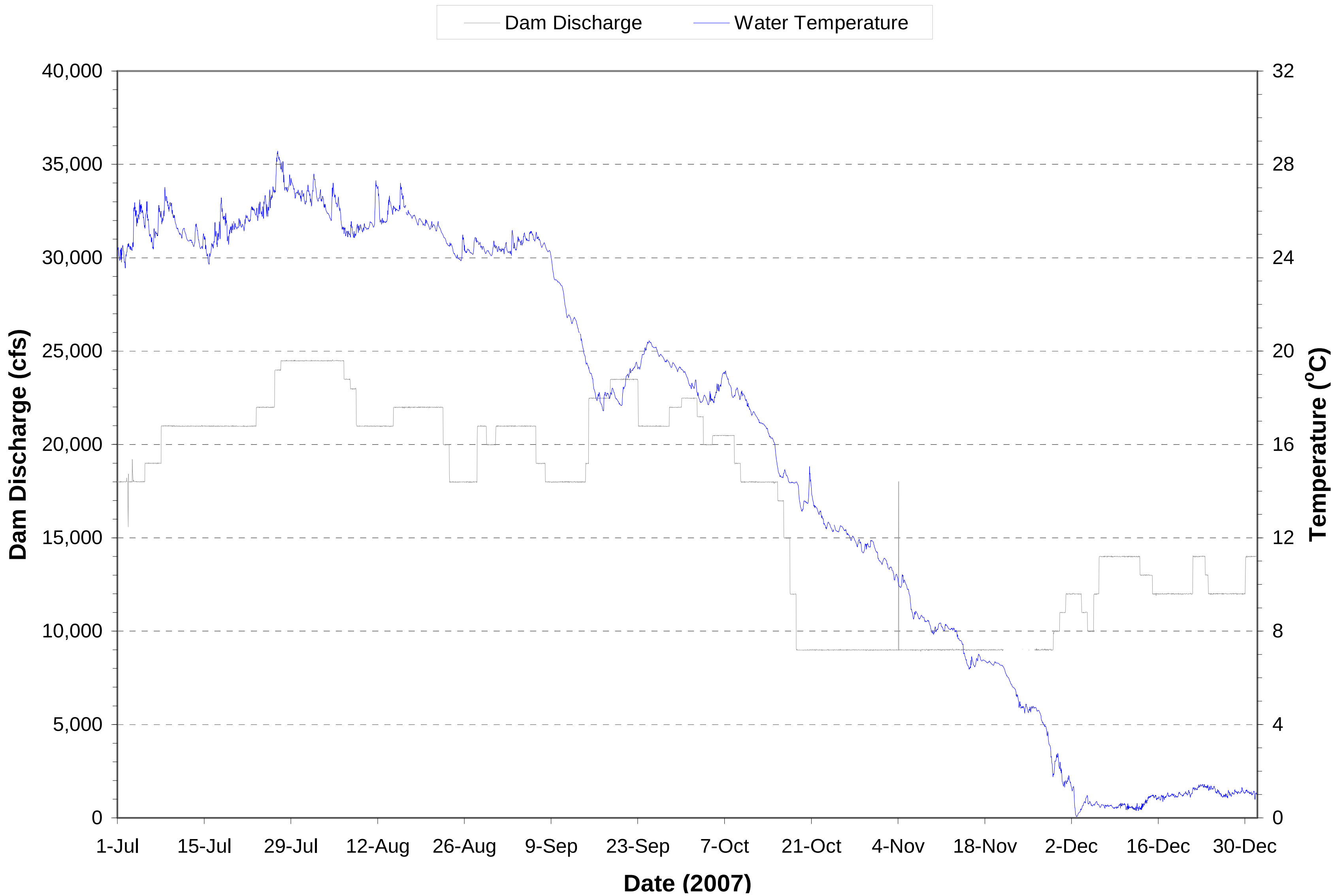


Plate 382. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2007.

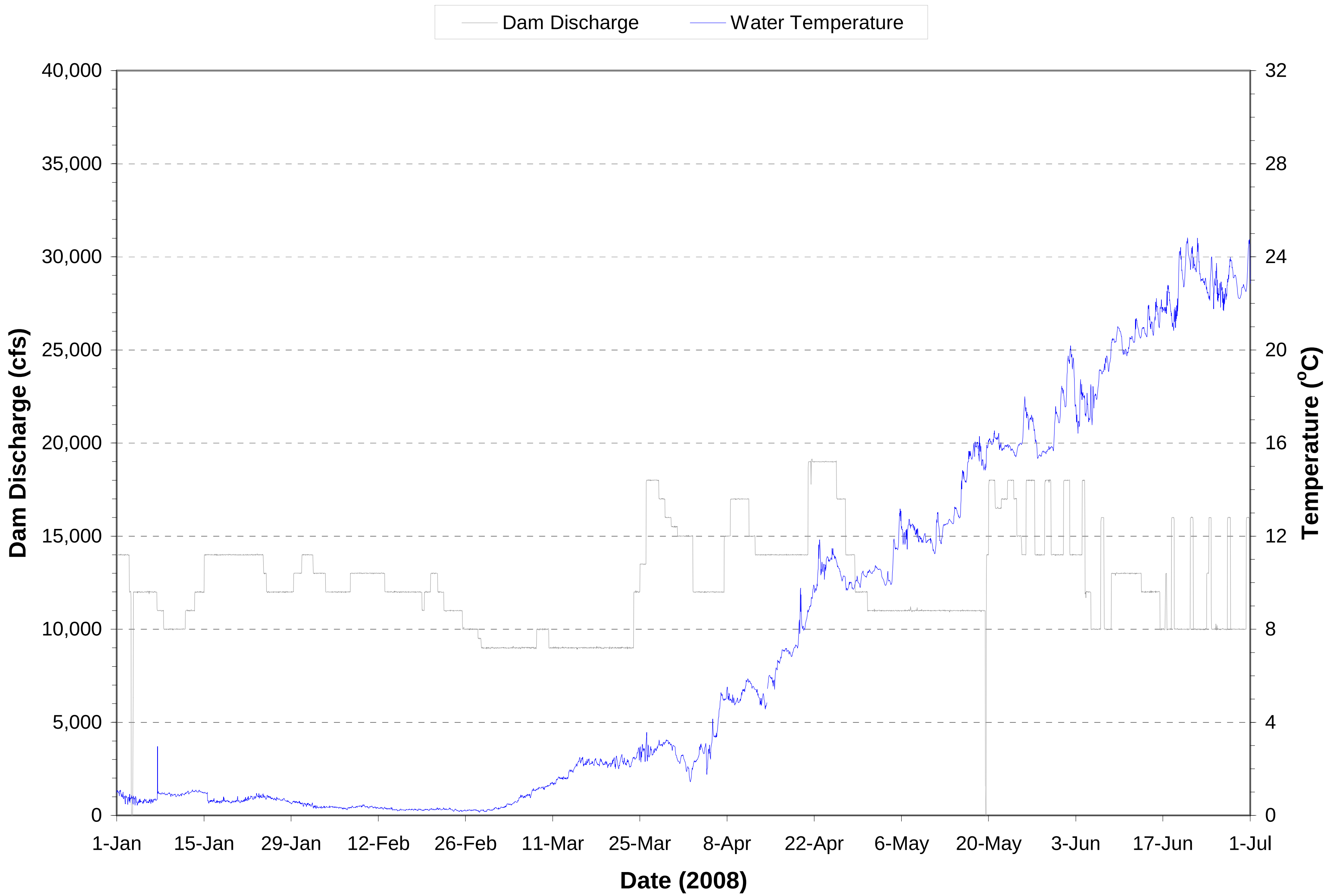


Plate 383. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2008.

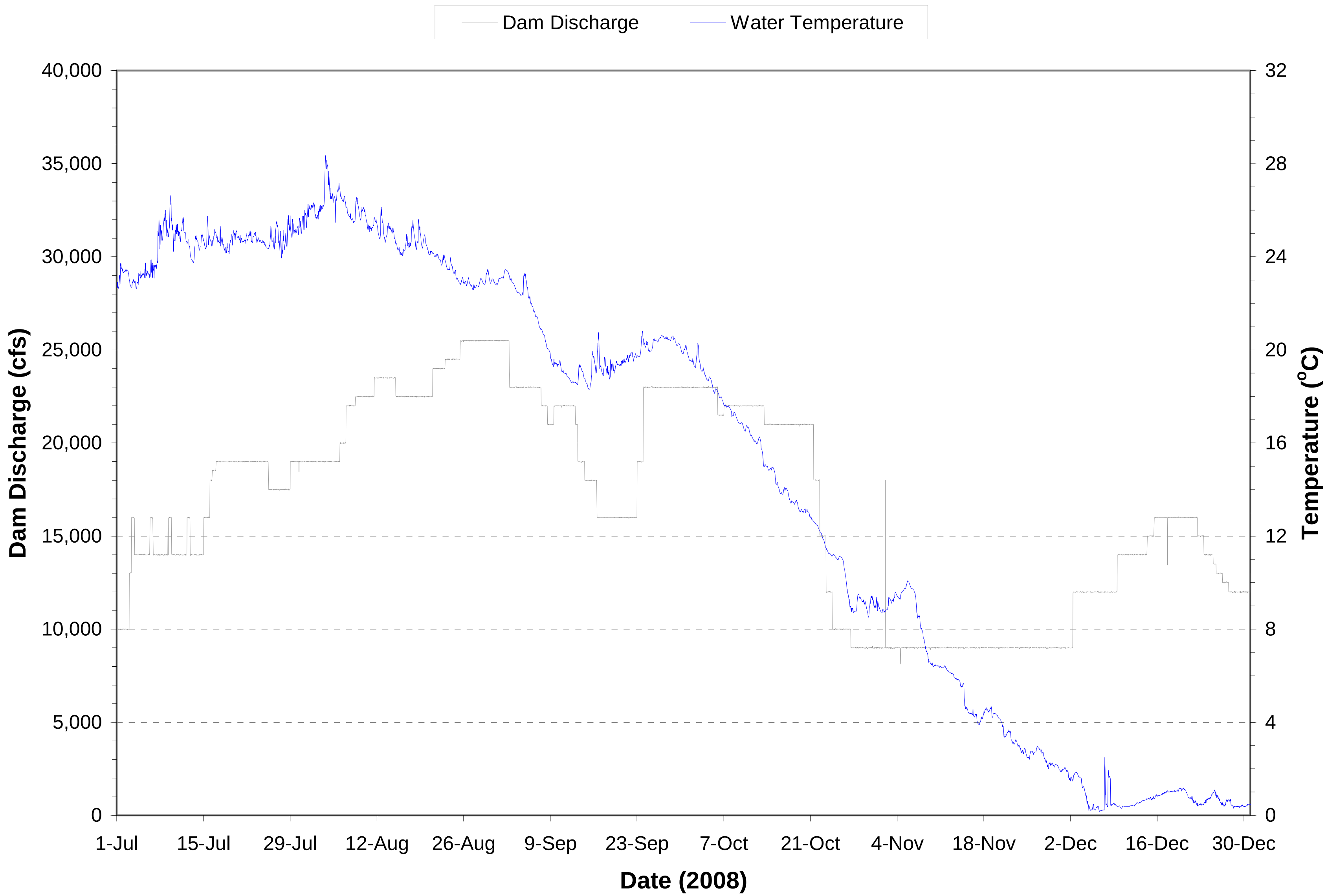


Plate 384. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2008.

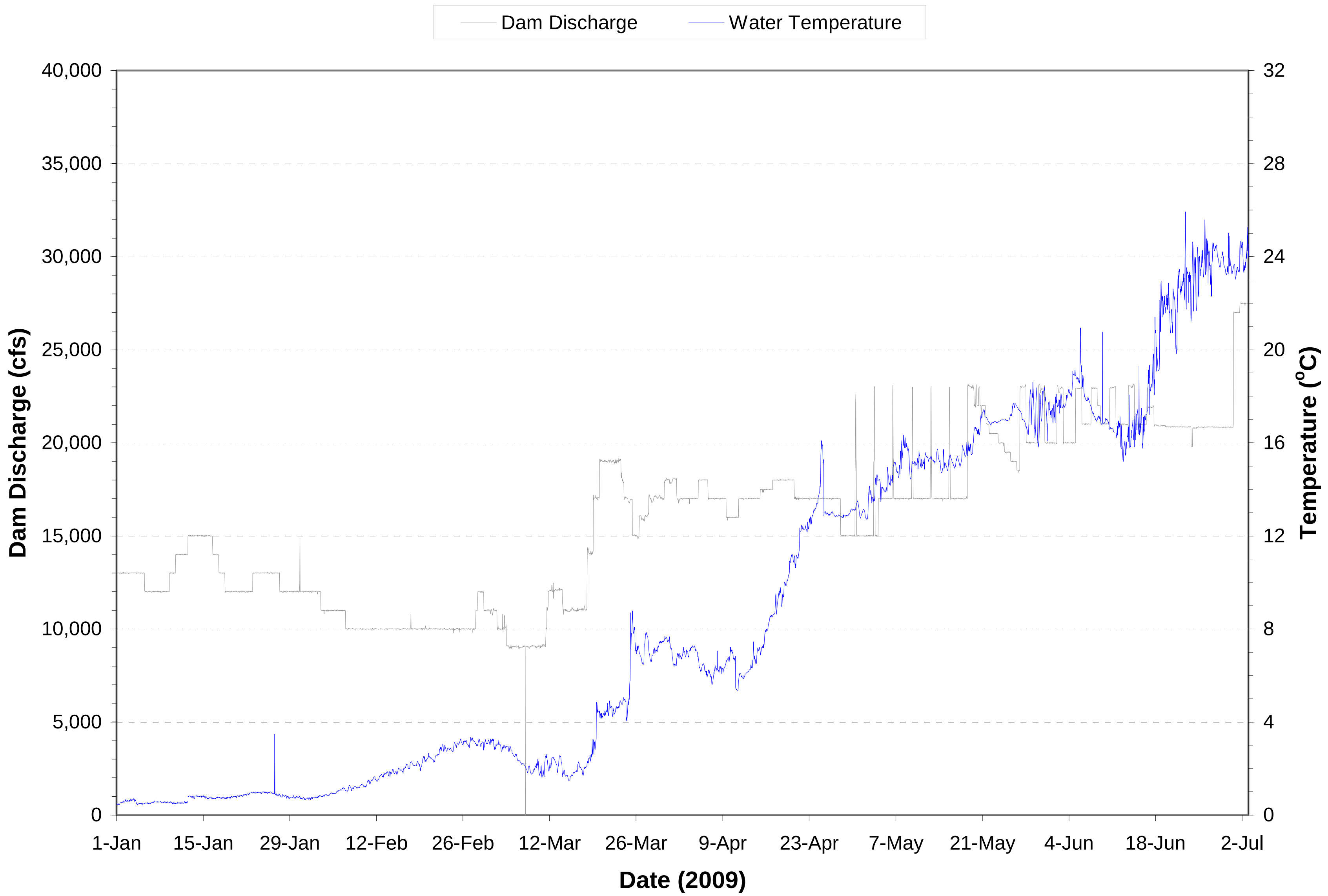


Plate 385. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2009.

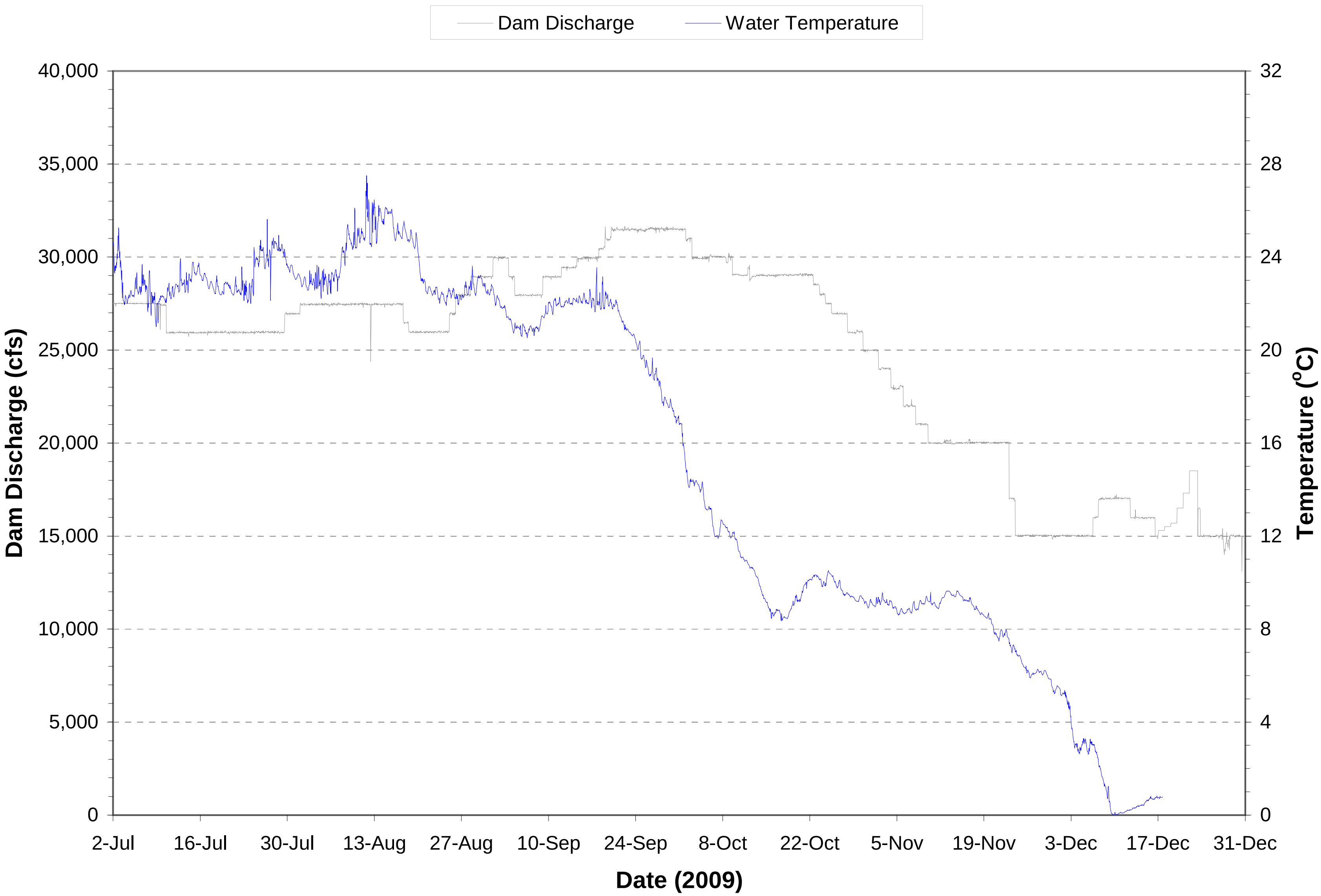


Plate 386. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2009.

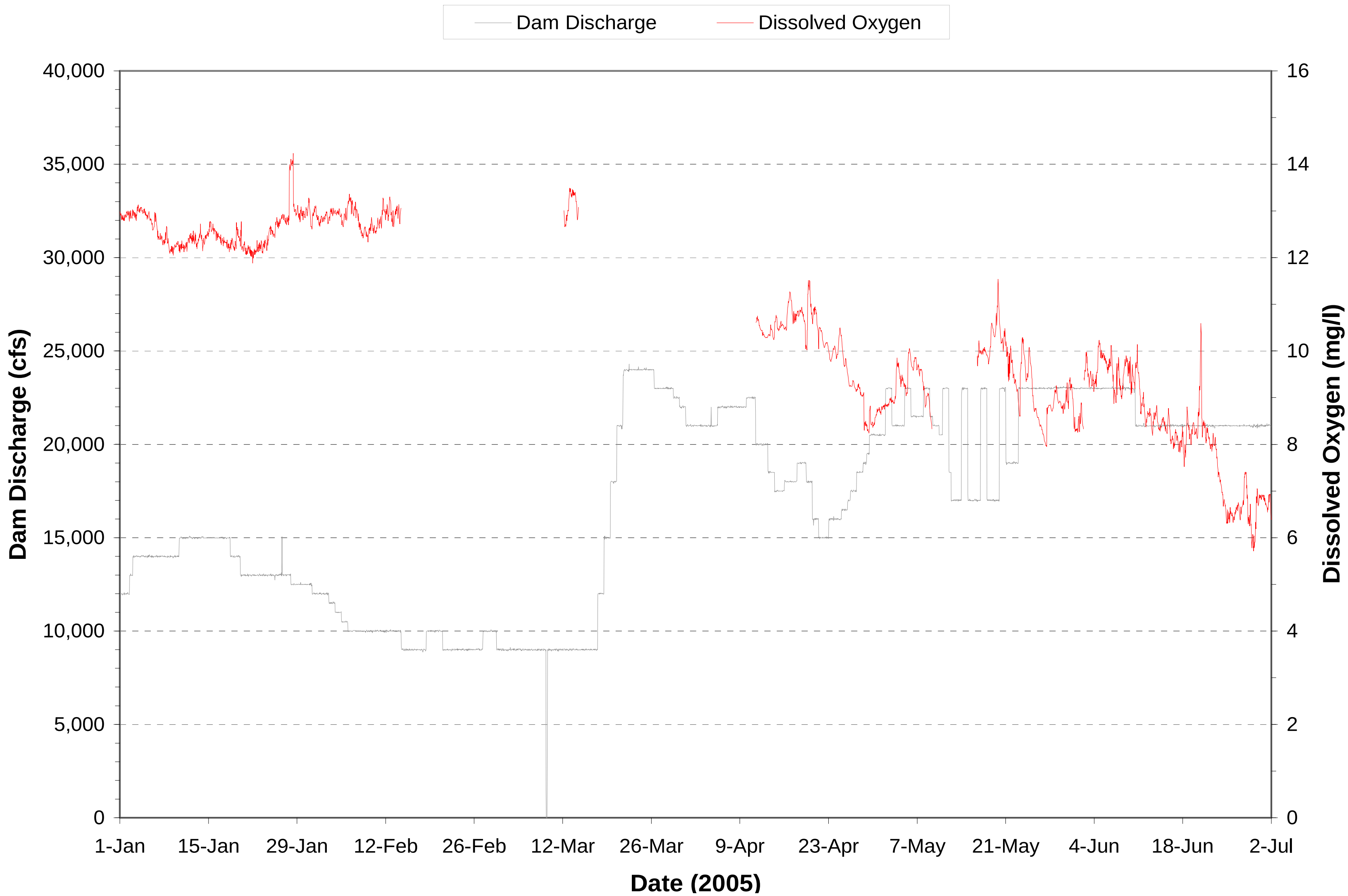


Plate 387. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2005.
Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

Plate 388. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2005.
Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

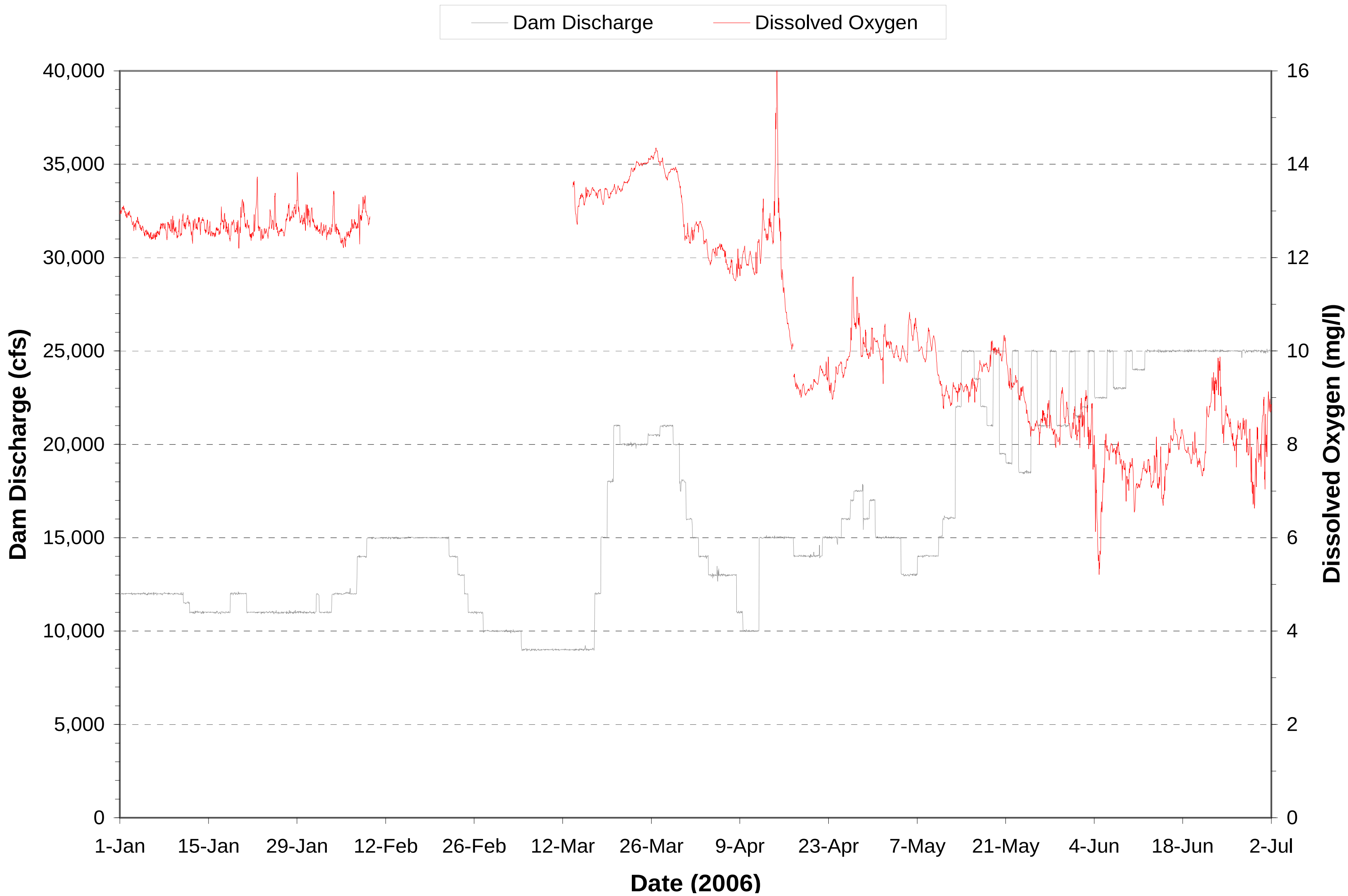


Plate 389. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2006.
Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

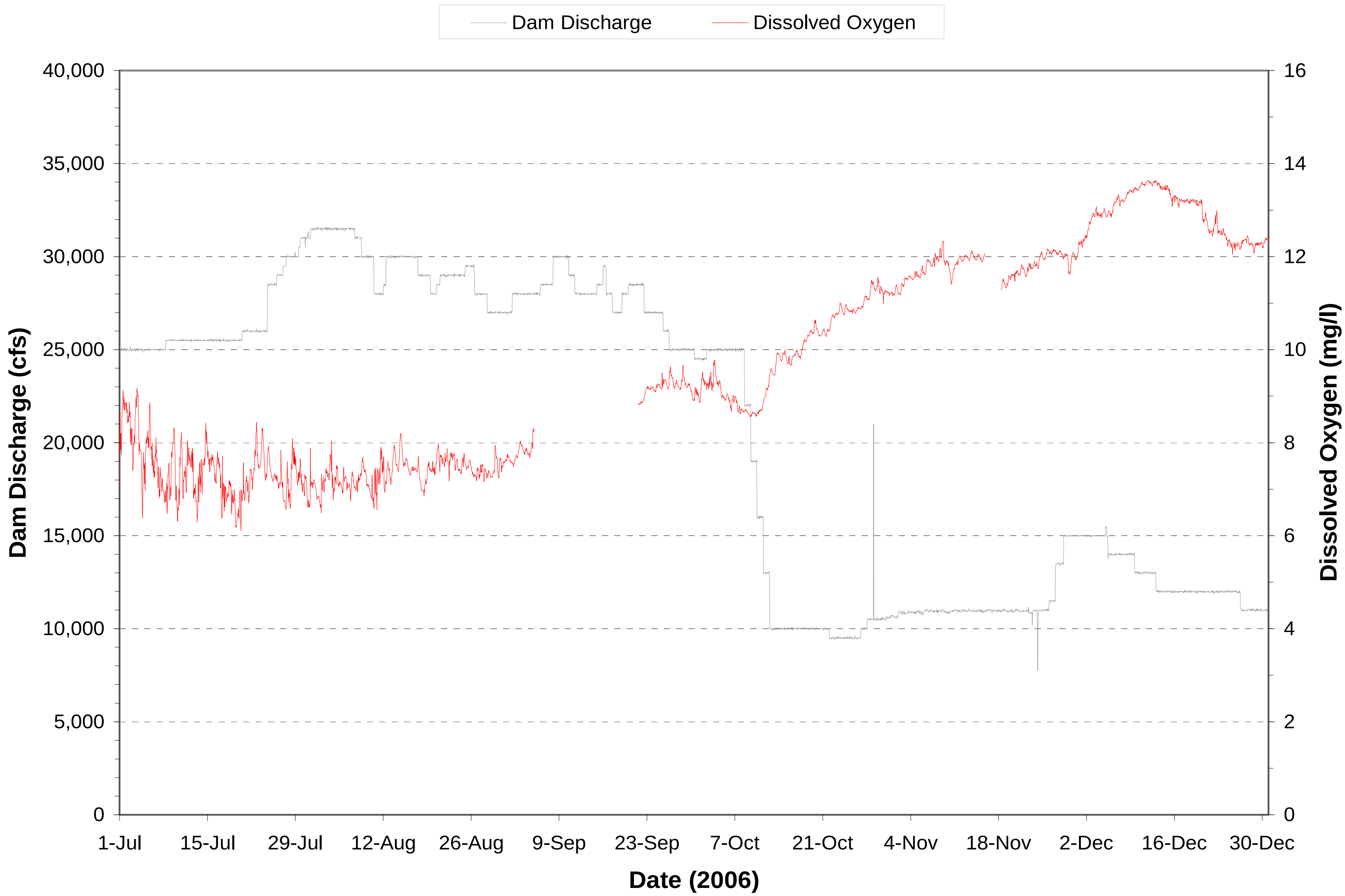


Plate 390. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2006.
Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

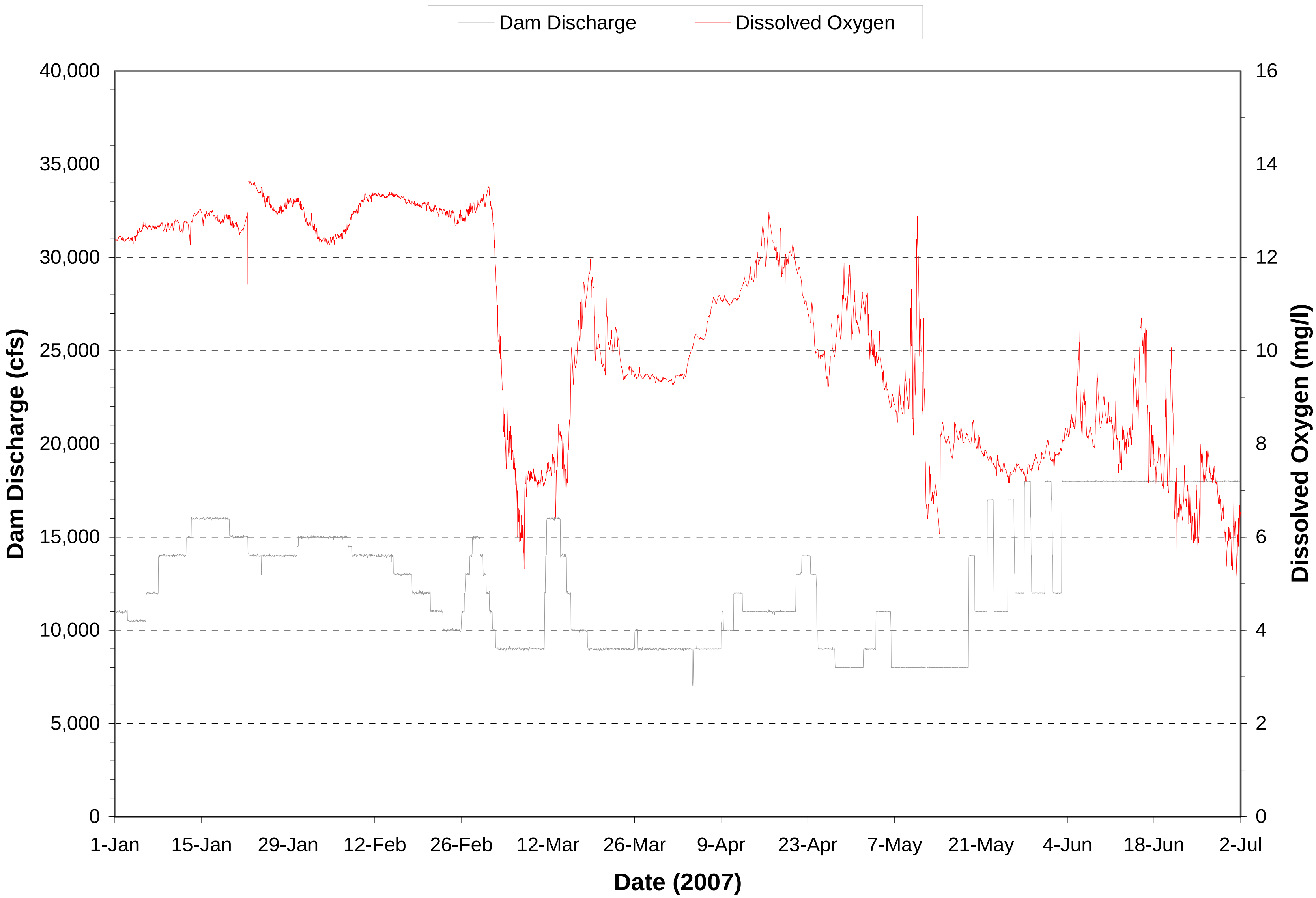


Plate 391. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2007.

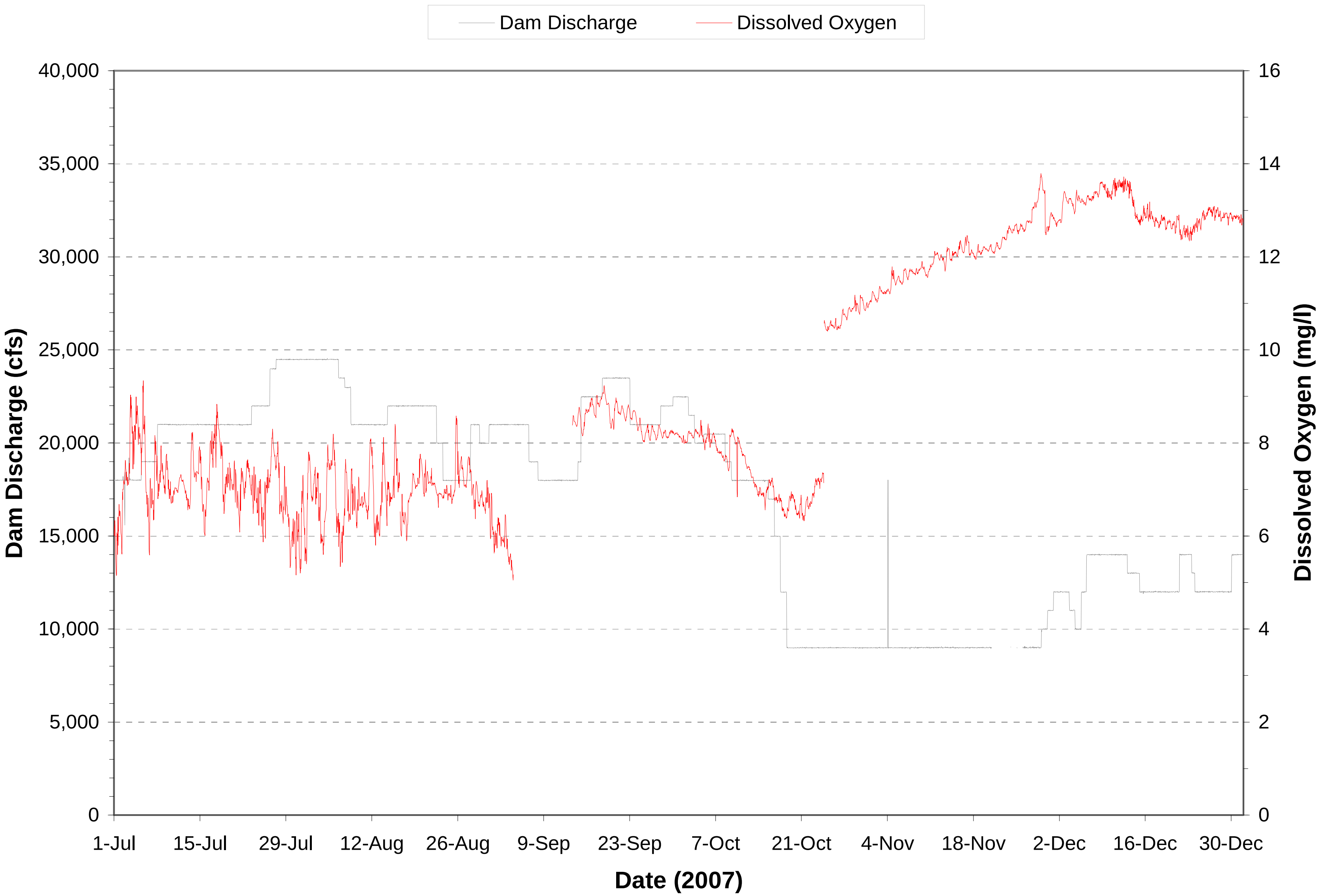


Plate 392. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2007.
Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

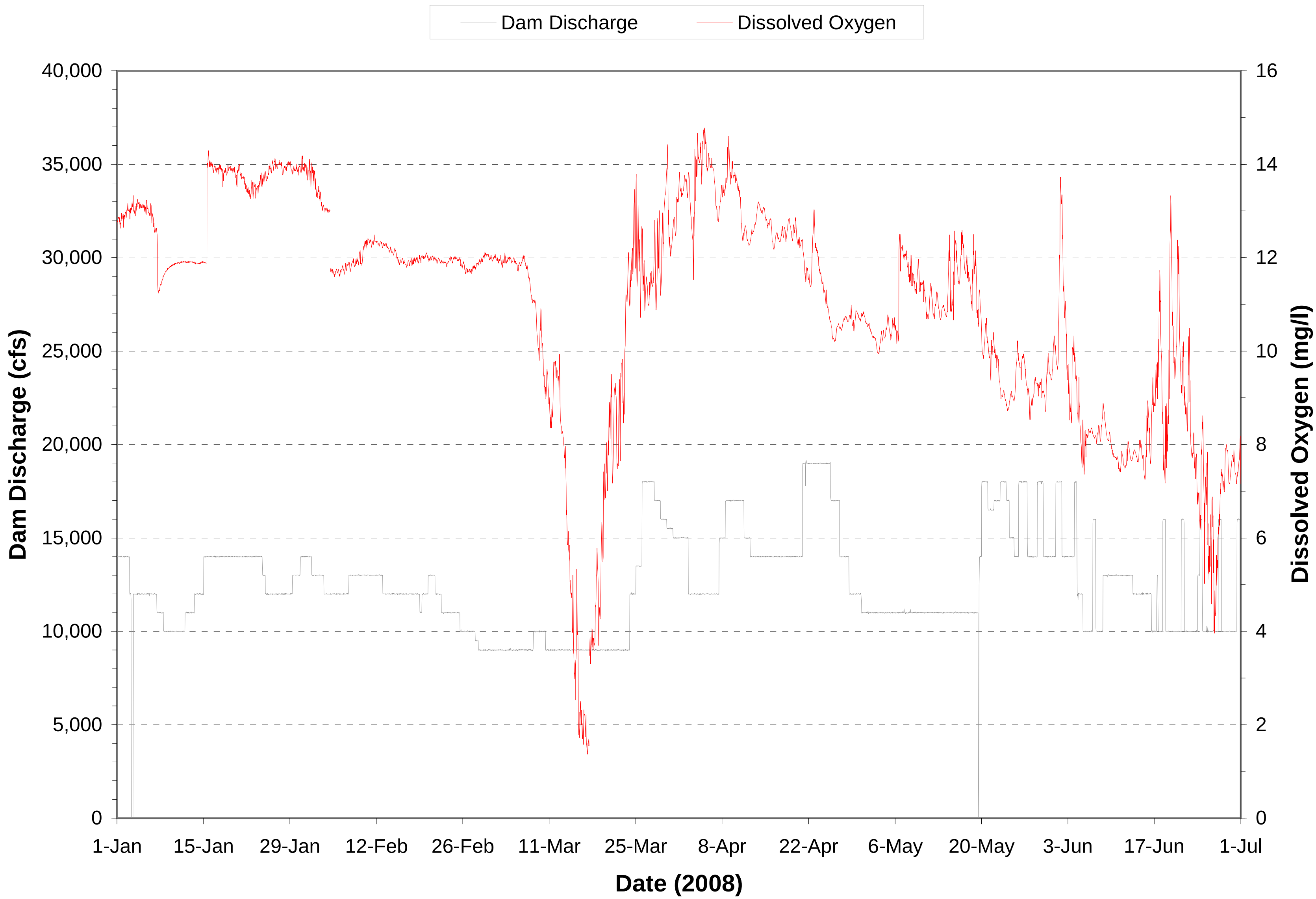


Plate 393. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2008.

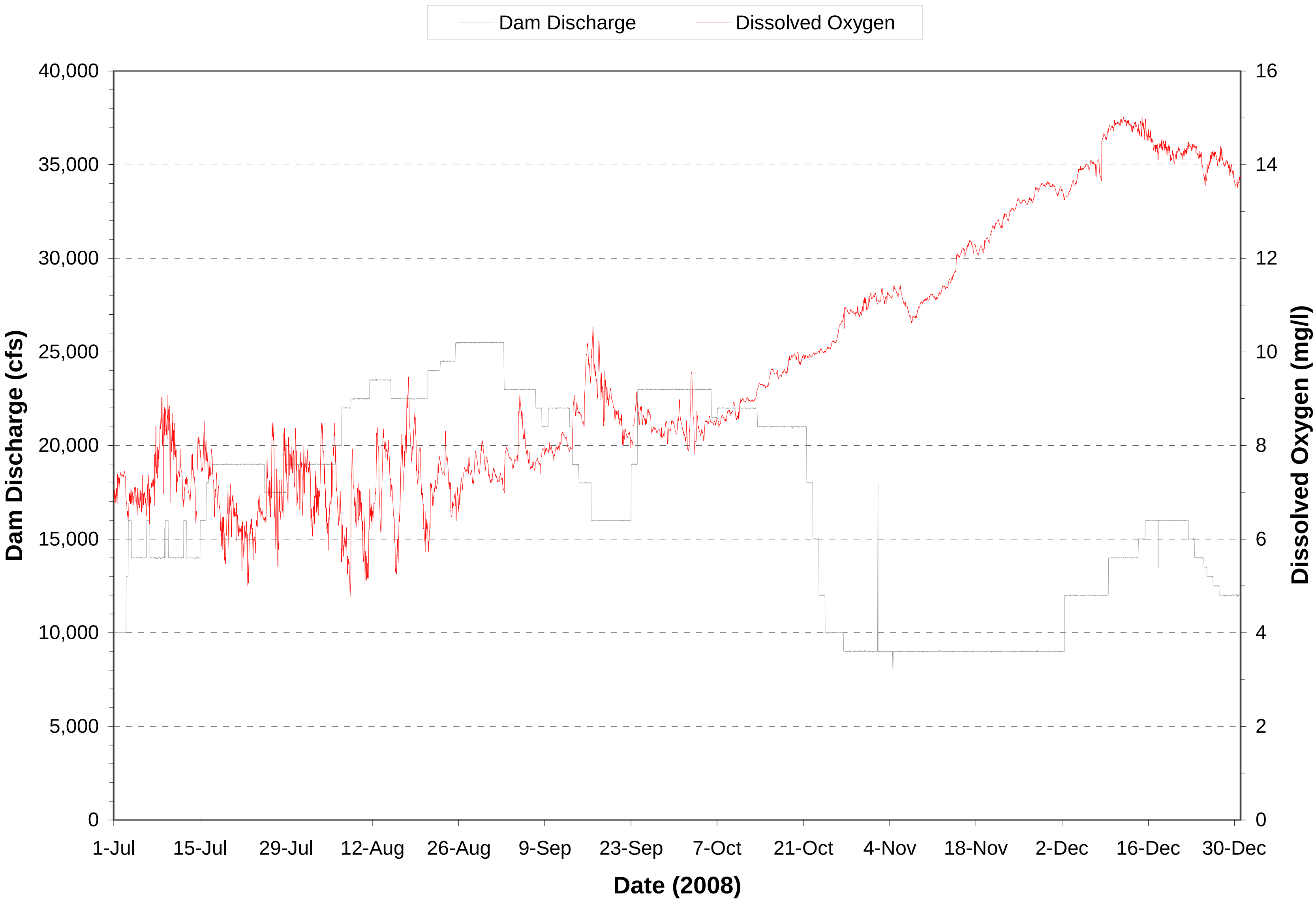


Plate 394. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2008.

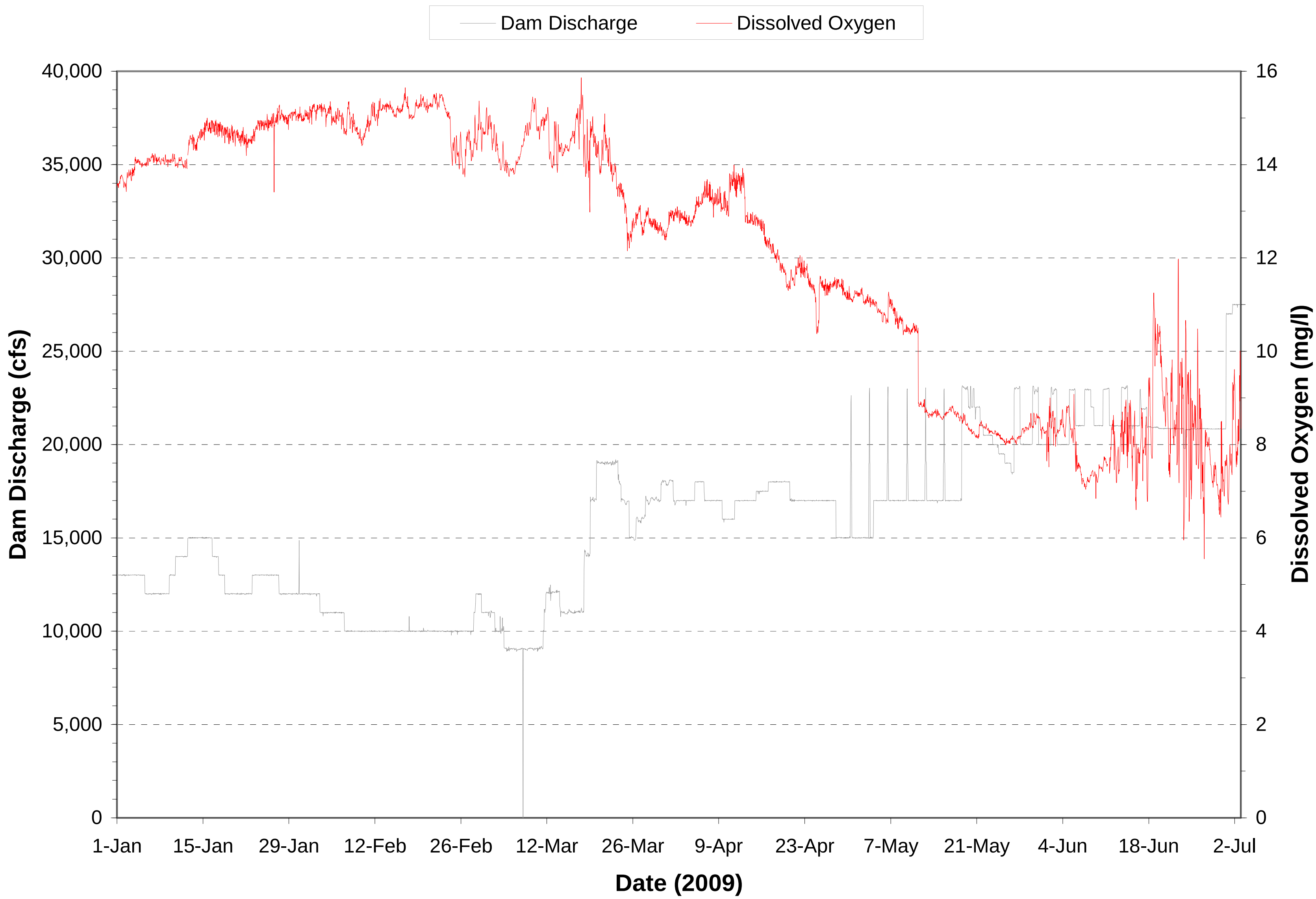


Plate 395. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2009.

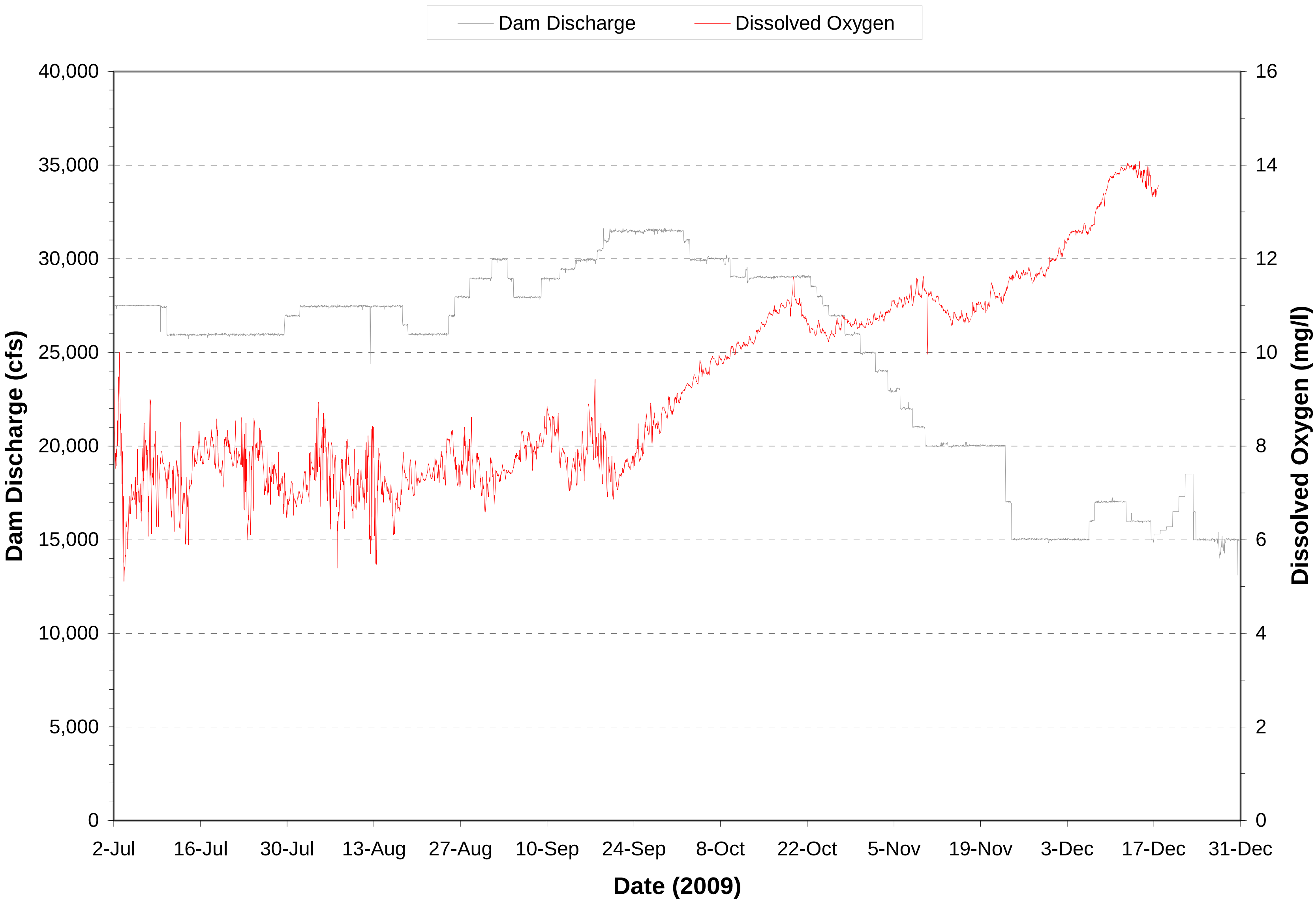


Plate 396. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2009.

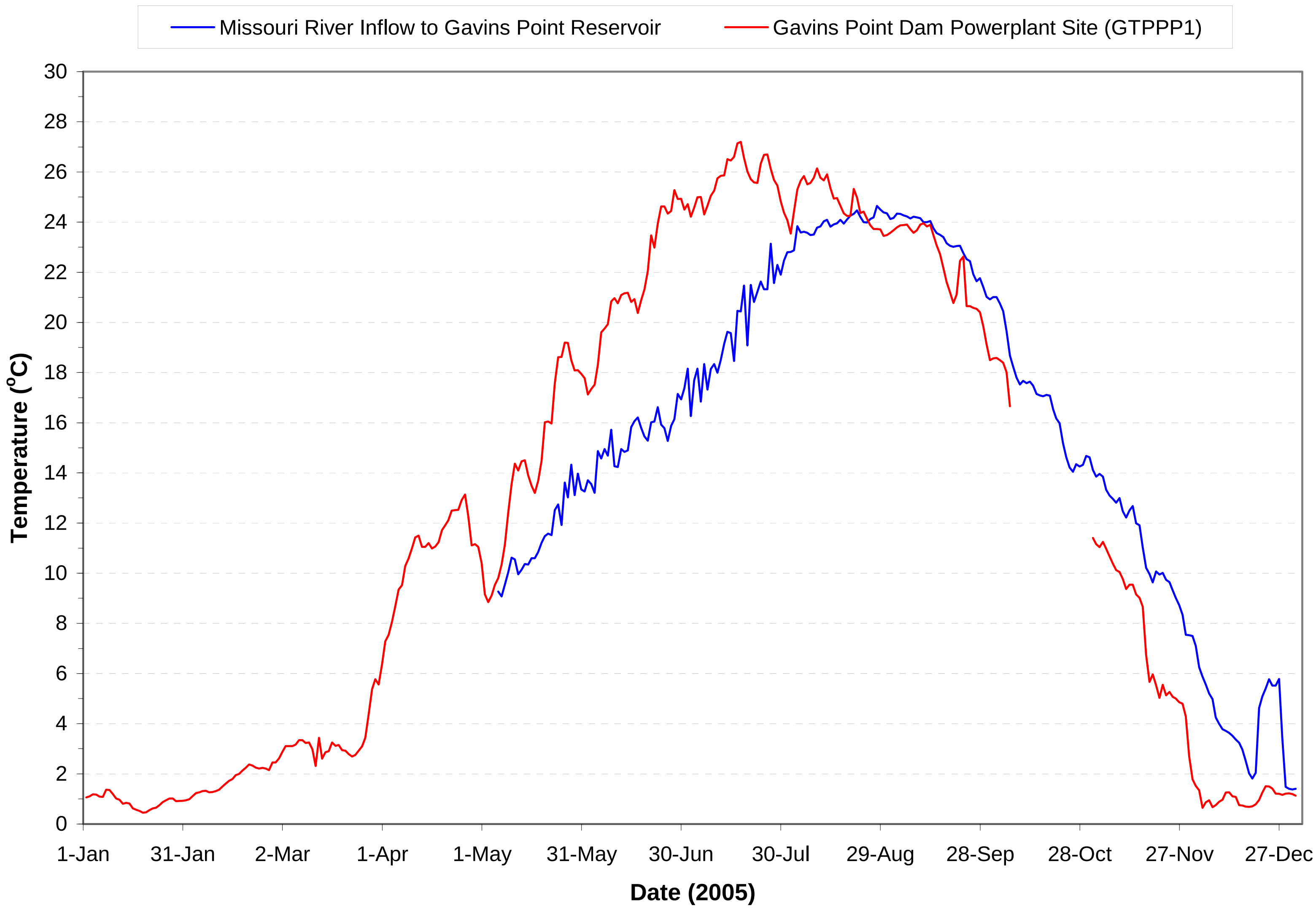


Plate 397. Mean daily water temperatures monitored at the Gavins Point Powerplant (i.e., site GTPPP1) and estimated for the Missouri River inflow to Lewis and Clark Lake during 2005.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.

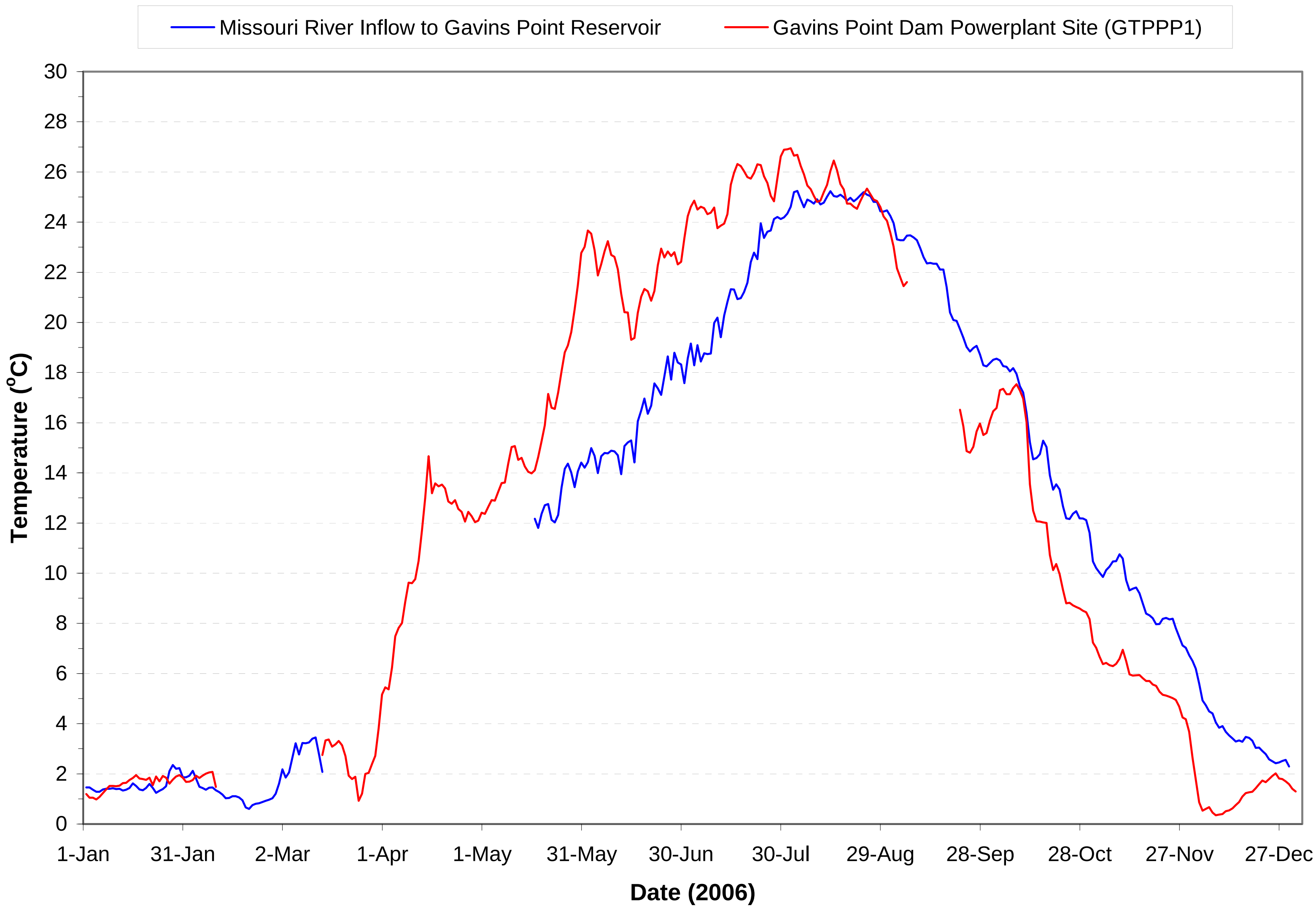


Plate 398. Mean daily water temperatures monitored at the Gavins Point Powerplant (i.e., site GTPPP1) and estimated for the Missouri River inflow to Lewis and Clark Lake during 2006.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.

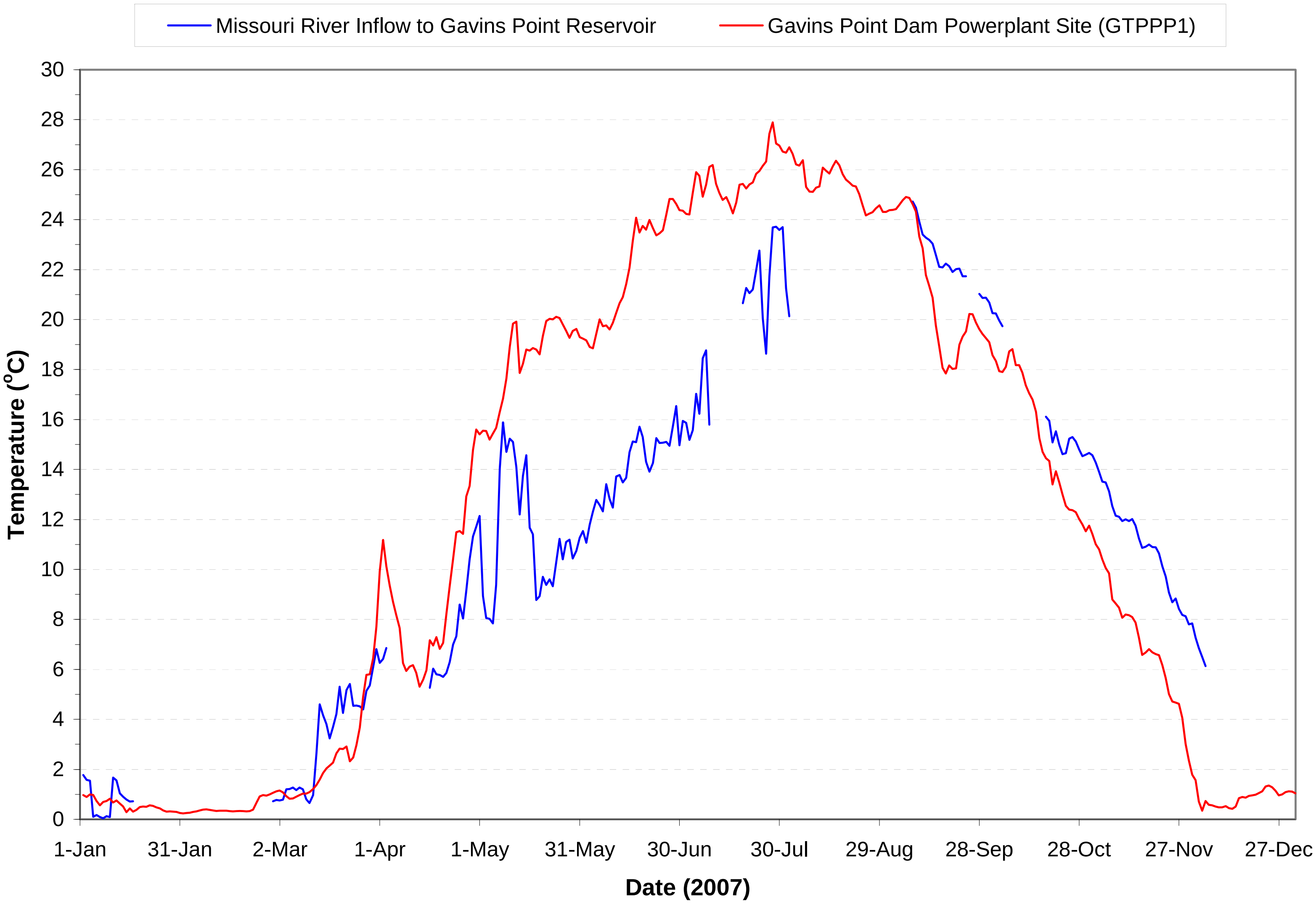


Plate 399. Mean daily water temperatures monitored at the Gavins Point Powerplant (i.e., site GTPPP1) and estimated for the Missouri River inflow to Lewis and Clark Lake during 2007.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.

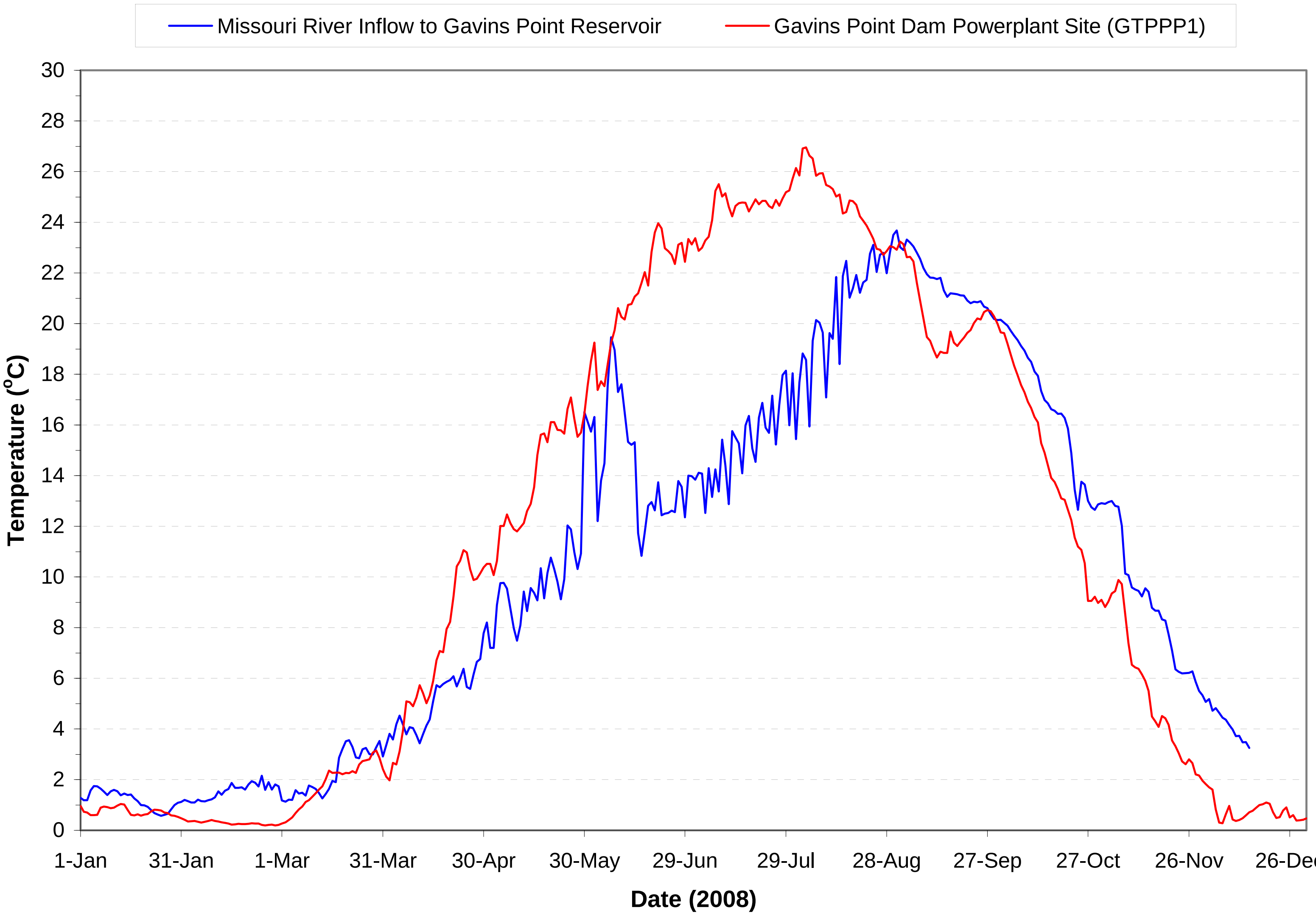


Plate 400. Mean daily water temperatures monitored at the Gavins Point Powerplant (i.e., site GTPPP1) and estimated for the Missouri River inflow to Lewis and Clark Lake during 2008.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.

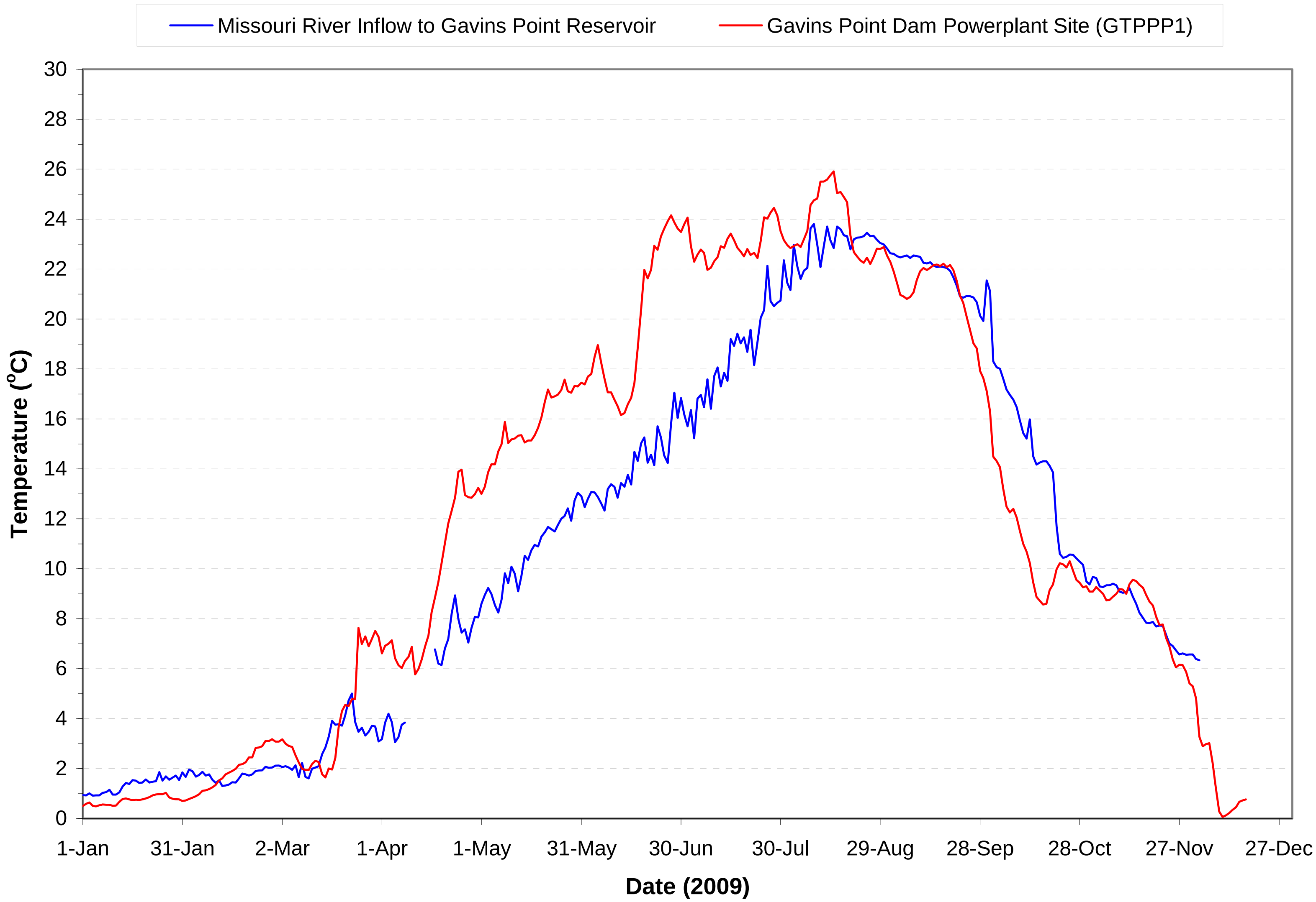


Plate 401. Mean daily water temperatures monitored at the Gavins Point Powerplant (i.e., site GTPPP1) and estimated for the Missouri River inflow to Lewis and Clark Lake during 2009.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.

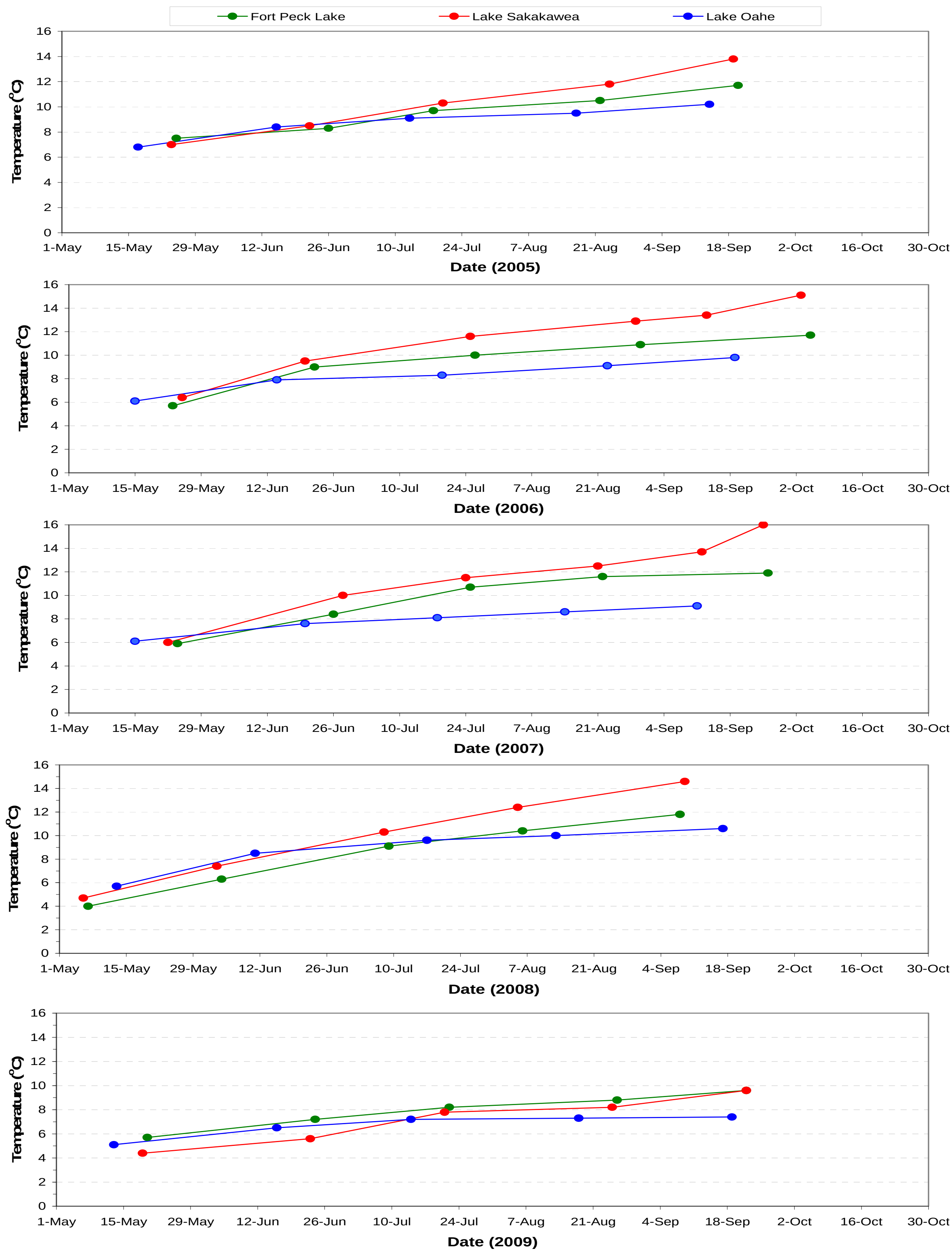


Plate 402. Near-bottom water temperatures measured at near-dam, deepwater locations in Fort Peck Lake, Lake Sakakawea, and Lake Oahe during the 5-year period 2005 through 2009.

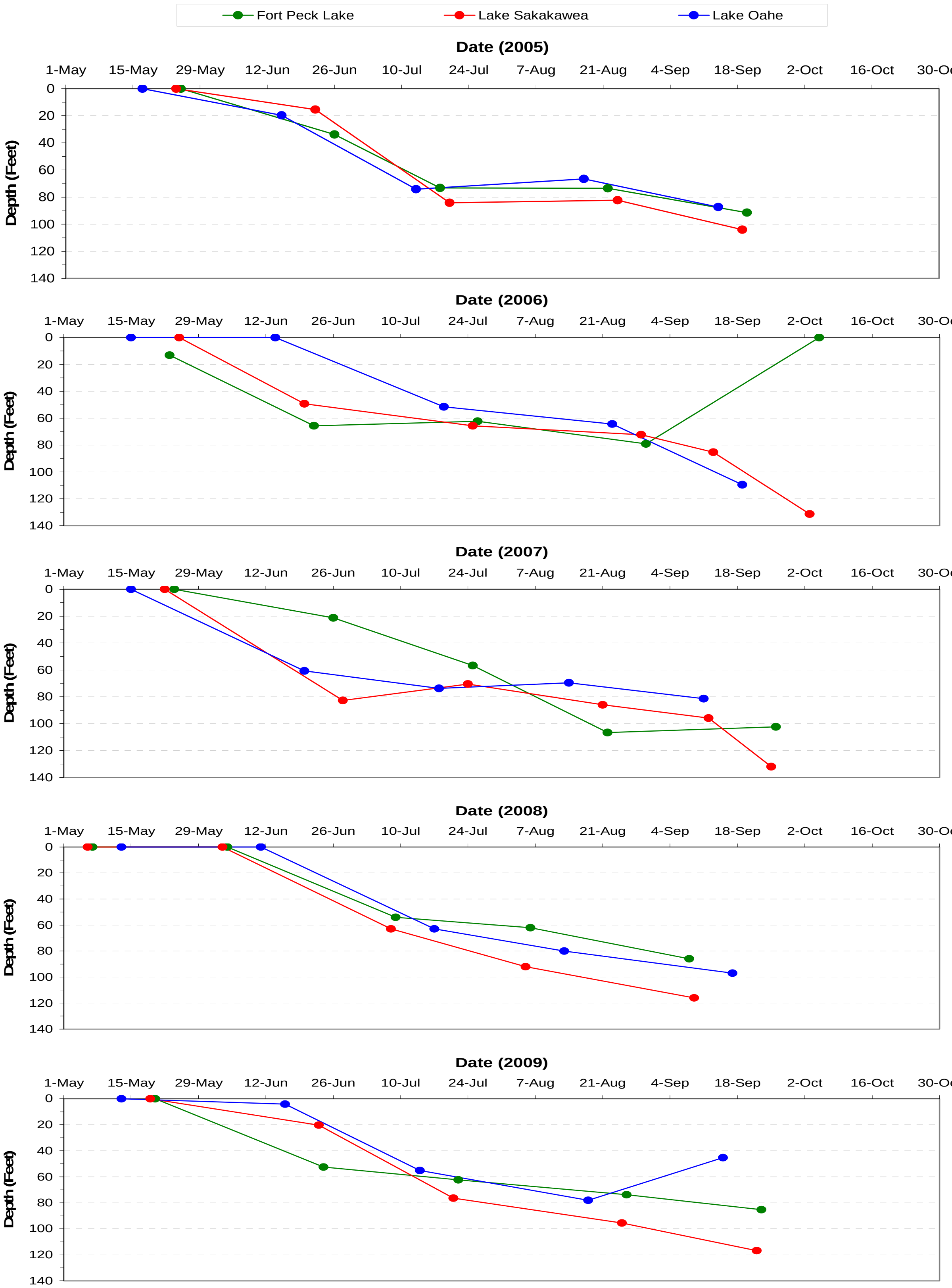


Plate 403. Depth to 15°C water temperature measured at near-dam, deepwater locations in Fort Peck Lake, Lake Sakakawea, and Lake Oahe for the 5-year period 2005 through 2009.

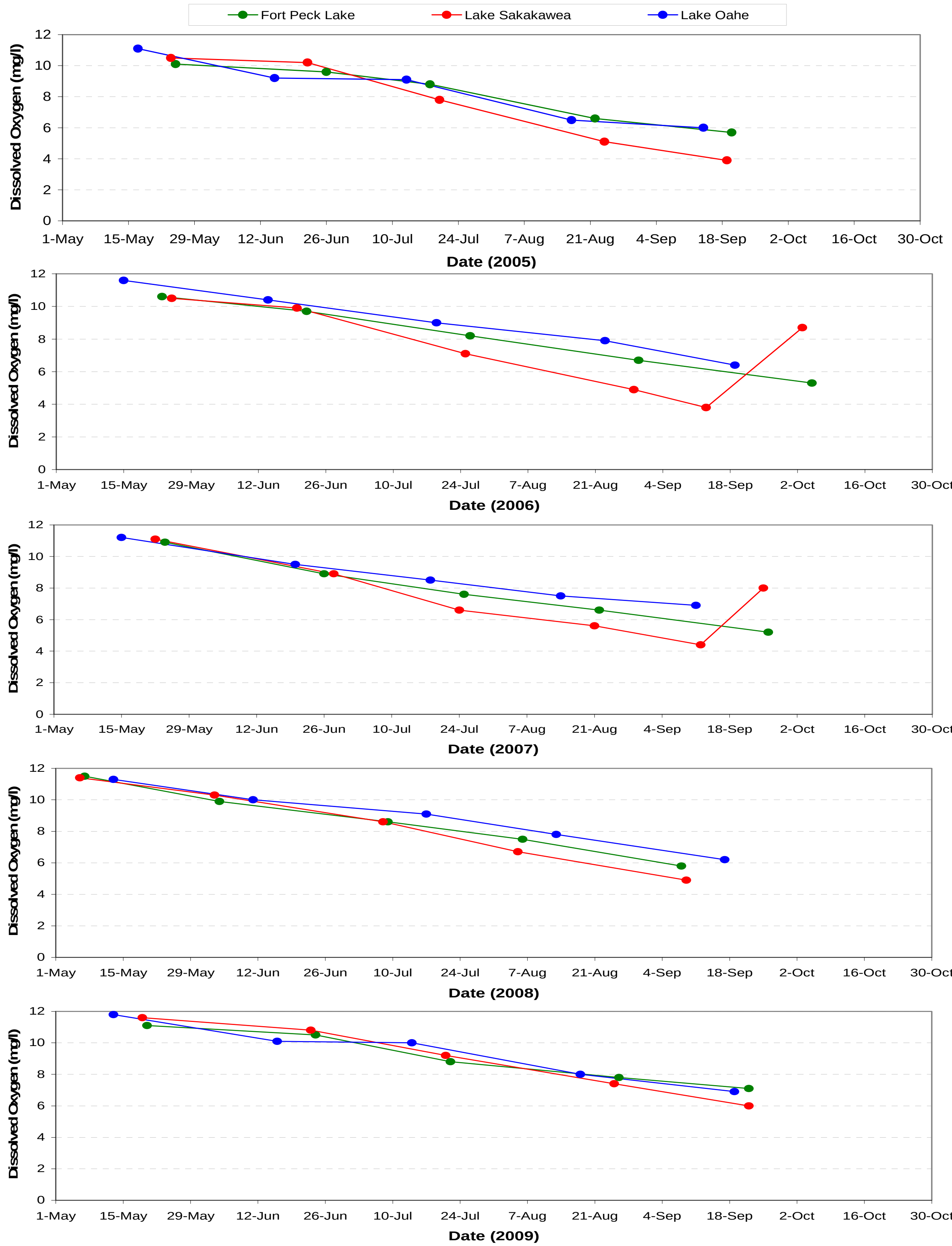


Plate 404. Near-bottom dissolved oxygen concentrations measured at near-dam, deepwater locations in Fort Peck Lake, Lake Sakakawea, and Lake Oahe during the 5-year period 2005 through 2009.

Plate 405. Summary of water quality conditions monitored in the Missouri River at the Gavins Point Dam tailwaters (i.e., site GPTRRTW1) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	80	17,775	17,146	8,000	30,963	-----	-----	-----
Water Temperature (°C)	0.1	78	13.7	13.9	0.0	27.1	27[1,2,6], 29[1,2,6]	1, 0	1%, 0%
Dissolved Oxygen (mg/l)	0.1	76	10.1	9.7	5.9	15.1	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	76	96.7	97.5	60.5	117.8	-----	-----	-----
Specific Conductance (umho/cm)	1	78	663	667	466	800	2,000[4]	0	0%
pH (S.U.)	0.1	76	8.3	8.3	7.6	8.7	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Oxidation-Reduction Potential	1	36	371	365	290	472	-----	-----	-----
Alkalinity, Total (mg/l)	7	79	161	160	130	190	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	77	3.4	3.2	2.3	7.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	79	10	10	n.d.	23	-----	-----	-----
Chloride (mg/l)	1	78	11	11	4	29	438[3,6], 250[3,8]	0	0%
Dissolved Solids, Total (mg/l)	5	58	459	460	350	550	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	0	0%
Hardness, Total (mg/l)	0.4	15	220	221	179	240	-----	-----	-----
Nitrogen, Ammonia Total	0.02	79	-----	0.04	n.d.	0.56	4.7 [1,6,9], 1.4 [1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	79	0.6	0.5	n.d.	1.8	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	78	-----	0.07	n.d.	0.60	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	78	0.7	0.6	n.d.	2.3	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	79	0.05	0.04	n.d.	0.23	-----	-----	-----
Suspended Solids, Total (mg/l)	4	79	9	9	n.d.	68	158[1,6], 90[1,8]	0	0%
Turbidity (NTU)	1	76	22	17	n.d.	85	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	11	-----	n.d.	n.d.	50	750[10], 87[11], 200[12]	0	0%
Antimony, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	1.0	88[10], 30[11], 6[12]	0	0%
Arsenic, Dissolved (ug/l)	1	11	2	2	n.d.	3	340[10], 16.7[11], 10[12]	0	0%
Barium, Dissolved (ug/l)	5	11	50	48	33	65	2,000[11]	0	0%
Beryllium, Dissolved (ug/l)	2	12	-----	n.d.	n.d.	n.d.	130[10], 5.3[11], 4[12]	0	0%
Cadmium, Dissolved (ug/l)	0.5	19	-----	n.d.	n.d.	n.d.	13[10], 0.43[11], 5[12]	0	0%
Chromium, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	1,134[10], 148[11], 100[12]	0	0%
Copper, Dissolved (ug/l)	2	18	-----	n.d.	n.d.	4	28[10], 18[11], 1,000[12]	0	0%
Lead, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	n.d.	151[10], 5.9[11], 15[12]	0	0%
Mercury, Dissolved (ug/l)	0.05	19	-----	n.d.	n.d.	n.d.	1.4[10]	0	0%
Mercury, Total (ug/l)	0.05	19	-----	n.d.	n.d.	n.d.	0.77[11], 2[12]	0	0%
Nickel, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	916[10], 102[11], 100[12]	0	0%
Selenium, Total (ug/l)	1	12	3	3	n.d.	4	20[4,10], 5[11], 50[12]	0	0%
Silver, Dissolved (ug/l)	1	19	-----	n.d.	n.d.	n.d.	14[10], 100[12]	0	0%
Thallium, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	n.d.	1,400[10], 6.3[11], 2[12]	0	0%
Zinc, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	11	229[10,11], 5,000[12]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	19	-----	n.d.	n.d.	0.40	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	47	-----	n.d.	n.d.	n.d.	760[10], 76[11], 2[12]	0	0%
Atrazine, Total (ug/l)[D]	0.05	66	-----	n.d.	n.d.	0.30	330[10], 12[11], 3[3]	0	0%
Metolachlor, Total (ug/l)[D]	0.05	66	-----	n.d.	n.d.	0.10	390[10], 100[11]	0	0%
Pesticide Scan (ug/l)[E]	0.05	12					-----	-----	-----
Atrazine, Total (ug/l)			-----	n.d.	n.d.	0.20	330[10], 12[11], 3[3]	0	0%
THM Formation Potential, Total (mg/l)	4	8	172	166	152	203	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (11) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (12) Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan. Individual pesticides were not detected unless listed under pesticide scan.

Plate 406. Summary of water quality conditions monitored in the Missouri River near Maskell, Nebraska (i.e., site MORRR0774) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	65	20,617	22,114	9,161	31,274	-----	-----	-----
Water Temperature (°C)	0.1	66	16.5	18.8	0.1	29.1	27[1,2,6], 29[1,2,6]	3, 1	5%, 2%
Dissolved Oxygen (mg/l)	0.1	65	9.8	9.3	6.0	14.2	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	65	101.3	101.6	68.7	121.0	-----	-----	-----
Specific Conductance (umho/cm)	1	66	678	688	471	780	2,000[4]	0	0%
pH (S.U.)	0.1	64	8.4	8.4	7.7	8.7	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Oxidation-Reduction Potential	1	29	365	358	255	481	-----	-----	-----
Alkalinity, Total (mg/l)	7	68	166	165	140	205	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	66	3.6	3.3	1.7	8.1	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	68	13	12	n.d.	27	-----	-----	-----
Chloride (mg/l)	1	68	12	12	4	31	438[3,6], 250[3,8]	0	0%
Dissolved Solids, Total (mg/l)	5	49	478	470	416	554	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	0	0%
Hardness, Total (mg/l)	0.4	14	240	235	212	342	-----	-----	-----
Nitrogen, Ammonia Total	0.02	68	-----	0.04	n.d.	0.54	3.9 [1,6,9], 1.0 [1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	68	0.7	0.5	n.d.	2.0	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	68	0.19	0.11	n.d.	1.30	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	68	0.8	0.7	0.2	2.4	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	68	0.09	0.06	n.d.	0.40	-----	-----	-----
Suspended Solids, Total (mg/l)	4	68	35	23	n.d.	204	158[1,6], 90[1,8]	3, 6	4%, 9%
Turbidity (NTU)	1	65	37	25	3	238	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	10	-----	n.d.	n.d.	60	750[10], 87[11], 200[12]	0	0%
Antimony, Dissolved (ug/l)	0.5	10	----	n.d.	n.d.	1.0	88[10], 30[11], 6[12]	0	0%
Arsenic, Dissolved (ug/l)	1	17	-----	1	n.d.	3	340[10], 16.7[11], 10[12]	0	0%
Barium, Dissolved (ug/l)	5	10	56	55	48	73	2,000[11]	0	0%
Beryllium, Dissolved (ug/l)	2	11	-----	n.d.	n.d.	n.d.	130[10], 5.3[11], 4[12]	0	0%
Cadmium, Dissolved (ug/l)	0.5	17	-----	n.d.	n.d.	n.d.	13[10], 0.43[11], 5[12]	0	0%
Chromium, Dissolved (ug/l)	10	17	-----	n.d.	n.d.	n.d.	1,134[10], 148[11], 100[12]	0	0%
Copper, Dissolved (ug/l)	2	16	-----	n.d.	n.d.	3	28[10], 18[11], 1,000[12]	0	0%
Lead, Dissolved (ug/l)	0.5	10	-----	n.d.	n.d.	n.d.	151[10], 5.9[11], 15[12]	0	0%
Mercury, Dissolved (ug/l)	0.05	17	-----	n.d.	n.d.	n.d.	1.4[10]	0	0%
Mercury, Total (ug/l)	0.05	17	-----	n.d.	n.d.	n.d.	0.77[11], 2[12]	0	0%
Nickel, Dissolved (ug/l)	10	17	-----	n.d.	n.d.	n.d.	916[10], 102[11], 100[12]	0	0%
Selenium, Total (ug/l)	1	11	3	3	n.d.	4	20[4,10], 5[11], 50[12]	0	0%
Silver, Dissolved (ug/l)	1	17	-----	n.d.	n.d.	n.d.	14[10], 100[12]	0	0%
Thallium, Dissolved (ug/l)	0.5	10	-----	n.d.	n.d.	n.d.	1,400[10], 6.3[11], 2[12]	0	0%
Zinc, Dissolved (ug/l)	10	17	-----	n.d.	n.d.	97	229[10,11], 5,000[12]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	14	-----	n.d.	n.d.	0.50	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	44	-----	n.d.	n.d.	0.13	760[10], 76[11], 2[12]	0	0%
Atrazine, Total (ug/l)[D]	0.05	58	-----	n.d.	n.d.	3.7	330[10], 12[11], 3[3]	0, 0, 1	0%, 0%, 2%
Metolachlor, Total (ug/l)[D]	0.05	58	-----	n.d.	n.d.	0.50	390[10], 100[11]	0	0%
Pesticide Scan (ug/l)[E]	0.05	10					-----	-----	-----
Acetochlor, Total (ug/l)			-----	n.d.	n.d.	0.30	-----	-----	----
Atrazine, Total (ug/l)			-----	n.d.	n.d.	0.20	330[10], 12[11], 3[3]	0	0%

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (11) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (12) Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan. Individual pesticides were not detected unless listed under pesticide scan.

Plate 407. Summary of water quality conditions monitored in the Missouri River near Ponca, Nebraska (i.e., site MORRR0753) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	65	21,038	22,757	9,247	32,704	-----	-----	-----
Water Temperature (°C)	0.1	66	16.5	18.9	0.3	30.6	27[1,2,6], 29[1,2,6]	4, 2	6%, 3%
Dissolved Oxygen (mg/l)	0.1	65	11.1	9.4	7.3		5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	65	100.6	100.0	60.8	125.2	-----	-----	-----
Specific Conductance (umho/cm)	1	66	696	712	469	894	2,000[4]	0	0%
pH (S.U.)	0.1	64	8.4	8.4	7.7	8.7	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Oxidation-Reduction Potential	1	30	366	357	270	477	-----	-----	-----
Alkalinity, Total (mg/l)	7	67	165	165	127	190	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	65	4.0	3.7	2.4	8.9	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	67	13	12	n.d.	45	-----	-----	-----
Chloride (mg/l)	1	67	12	11	5	26	438[3,6], 250[3,8]	0	0%
Dissolved Solids, Total (mg/l)	5	49	506	500	316	626	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	0	0%
Hardness, Total (mg/l)	0.4	13	244	246	213	279	-----	-----	-----
Nitrogen, Ammonia Total	0.02	67	-----	0.04	n.d.	0.37	3.9 [1,6,9], 1.0 [1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	67	0.8	0.6	0.3	4.3	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	67	-----	0.05	n.d.	1.10	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	67	0.9	0.7	0.3	5.2	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	67	0.12	0.08	n.d.	0.60	-----	-----	-----
Suspended Solids, Total (mg/l)	4	67	46	29	n.d.	352	158[1,6], 90[1,8]	4, 4	6%, 6%
Turbidity (NTU)	1	65	46	26	4	358	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	8	-----	n.d.	n.d.	690	750[10], 87[11], 200[12]	0, 1, 1	0%, 13%, 13%
Antimony, Dissolved (ug/l)	0.5	9	-----	n.d.	n.d.	0.7	88[10], 30[11], 6[12]	0	0%
Arsenic, Dissolved (ug/l)	1	9	3	3	2	3	340[10], 16.7[11], 10[12]	0	0%
Barium, Dissolved (ug/l)	5	9	57	57	48	66	2,000[11]	0	0%
Beryllium, Dissolved (ug/l)	2	10	-----	n.d.	n.d.	n.d.	130[10], 5.3[11], 4[12]	0	0%
Cadmium, Dissolved (ug/l)	0.5	16	-----	n.d.	n.d.	n.d.	14[10], 0.46[11], 5[12]	0	0%
Chromium, Dissolved (ug/l)	10	16	-----	n.d.	n.d.	n.d.	1,238[10], 161[11], 100[12]	0	0%
Copper, Dissolved (ug/l)	2	15	-----	n.d.	n.d.	3	31[10], 19[11], 1,000[12]	0	0%
Lead, Dissolved (ug/l)	0.5	9	-----	n.d.	n.d.	n.d.	169[10], 6.6[11], 15[12]	0	0%
Mercury, Dissolved (ug/l)	0.05	16	-----	n.d.	n.d.	n.d.	1.4[10]	0	0%
Mercury, Total (ug/l)	0.05	16	-----	n.d.	n.d.	n.d.	0.77[11], 2[12]	0	0%
Nickel, Dissolved (ug/l)	10	16	-----	n.d.	n.d.	n.d.	1,003[10], 111[11], 100[12]	0	0%
Selenium, Total (ug/l)	1	9	-----	2	n.d.	4	20[4,10], 5[11], 50[12]	0	0%
Silver, Dissolved (ug/l)	1	15	-----	n.d.	n.d.	n.d.	16[10], 100[12]	0	0%
Thallium, Dissolved (ug/l)	0.5	9	-----	n.d.	n.d.	n.d.	1,400[10], 6.3[11], 2[12]	0	0%
Zinc, Dissolved (ug/l)	10	16	-----	n.d.	n.d.	64	251[10,11], 5,000[12]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	14	-----	n.d.	n.d.	2.00	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	42	-----	n.d.	n.d.	n.d.	760[10], 76[11], 2[12]	0	0%
Atrazine, Total (ug/l)[D]	0.05	56	-----	n.d.	n.d.	1.00	330[10], 12[11], 3[3]	0	0%
Metolachlor, Total (ug/l)[D]	0.05	56	-----	n.d.	n.d.	1.3	390[10], 100[11]	0	0%
Pesticide Scan (ug/l)[E]	0.05	11					-----	-----	-----
Acetochlor, Total (mg/l)			-----	n.d.	n.d.	0.30	-----	-----	-----
Atrazine, Total (ug/l)			-----	n.d.	n.d.	0.40	330[10], 12[11], 3[3]	0	0%

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (11) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (12) Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan. Individual pesticides were not detected unless listed under pesticide scan.

Plate 408. Summary of water quality conditions monitored in the Missouri River at Decatur, Nebraska (i.e., site MORRR0691) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	78	24,221	25,250	11,500	42,400	-----	-----	-----
Water Temperature (°C)	0.1	77	15.1	16.0	0.0	29.8	32[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	76	9.8	9.2	6.4	14.9	5[1,6]	0	0%
Dissolved Oxygen (% Sat.)	0.1	76	96.6	98.0	60.9	118.1	-----	-----	-----
Specific Conductance (umho/cm)	1	77	737	739	489	956	2,000[3]	0	0%
pH (S.U.)	0.1	75	8.2	8.3	7.5	8.7	6.5[1,6], 9.0[1,5]	0	0%
Oxidation-Reduction Potential	1	37	373	360	212	516	-----	-----	-----
Alkalinity, Total (mg/l)	7	77	182	181	125	221	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	74	4.2	3.8	1.7	11.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	77	16	13	n.d.	76	-----	-----	-----
Chloride (mg/l)	1	77	16	16	8	24	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	57	530	520	338	790	-----	-----	-----
Hardness, Total (mg/l)	0.4	15	280	270	240	381	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	77	-----	0.06	n.d.	0.54	4.7 [1,5,8], 1.4 [1,7,8]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	77	1.0	0.8	0.3	5.0	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	76	1.16	0.90	n.d.	5.0	10[2,5], 100[3,5]	0	0%
Nitrogen, Total (mg/l)	0.1	76	2.2	1.7	0.3	6.8	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	77	0.19	0.13	n.d.	1.10	-----	-----	-----
Suspended Solids, Total (mg/l)	4	77	88	40	n.d.	580	-----	-----	-----
Turbidity (NTU)	1	76	64	35	4	325	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	10	-----	n.d.	n.d.	n.d.	750[9], 87[10], 200[2]	0	0%
Antimony, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	0.7	88[9], 30[10], 6[2]	0	0%
Arsenic, Dissolved (ug/l)	1	11	2	3	n.d.	4	340[9], 16.7[10,11], 10[2]	0	0%
Barium, Dissolved (ug/l)	5	11	65	63	52	83	2,000[2]	0	0%
Beryllium, Dissolved (ug/l)	2	12	-----	n.d.	n.d.	n.d.	130[5], 5.3[10], 4[2]	0	0%
Cadmium, Dissolved (ug/l)	0.5	19	-----	n.d.	n.d.	0.5	15[9], 0.49[10], 5[2]	0, 1, 0	0%, 5%, 0%
Chromium, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	1,335[9], 174[10], 100[2]	0	0%
Copper, Dissolved (ug/l)	2	18	-----	n.d.	n.d.	n.d.	34[9], 21[10], 1,000[2]	0	0%
Lead, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	1	187[9], 7.3[10]	0	0%
Mercury, Dissolved (ug/l)	0.05	19	-----	n.d.	n.d.	n.d.	1.4[9]	0	0%
Mercury, Total (ug/l)	0.05	19	-----	n.d.	n.d.	n.d.	0.77[10], 2[2]	0	0%
Nickel, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	1,085[9], 121[10]	0	0%
Selenium, Total (ug/l)	1	11	3	3	1	4	20[3,9], 5[10], 50[2]	0	0%
Silver, Dissolved (ug/l)	1	18	-----	n.d.	n.d.	n.d.	19[9], 100[2]	0	0%
Thallium, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	n.d.	1,400[5], 6.3[10,11], 2[2]	0	0%
Zinc, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	48	272[9,10], 5,000[2]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	19	-----	n.d.	n.d.	1.40	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	47	-----	n.d.	n.d.	0.20	760[9], 76[10], 2[2]	0	0%
Atrazine, Total (ug/l)[D]	0.05	66	-----	n.d.	n.d.	2.05	330[9], 12[10], 3[2]	0	0%
Metolachlor, Total (ug/l)[D]	0.05	66	-----	n.d.	n.d.	2.50	390[9], 100[10]	0	0%
Pesticide Scan (ug/l)[E]	0.05	10					-----	-----	-----
Acetochlor, Total (ug/l)			-----	n.d.	n.d.	0.15	-----	-----	-----
Atrazine, Total (ug/l)			-----	n.d.	n.d.	0.19	330[9], 12[10], 3[2]	0	0%

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of Class I Warmwater Aquatic Life (Nebraska).
(2) Criteria for the protection of domestic water supply waters.
(3) Criteria for the protection of agricultural water supply waters.
(4) Criteria for the protection of commerce and industry waters.
(5) Daily maximum criterion (monitoring results directly comparable to criterion).
(6) Daily minimum criterion (monitoring results directly comparable to criterion).
(7) 30-day average criterion (monitoring results not directly comparable to criterion).
(8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(9) Acute criterion for aquatic life.
(10) Chronic criterion for aquatic life.
(11) Criterion for the protection of human health.

Note: Some of Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

Plate 409. Summary of water quality conditions monitored in the Missouri River at Omaha, Nebraska (i.e., site MORRR0619) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	113	28,438	28,700	11,600	81,900	-----	-----	-----
Water Temperature (°C)	0.1	111	15.5	17.1	0.0	28.1	32[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	110	9.4	8.7	5.4	15.0	5[1,6]	0	0%
Dissolved Oxygen (% Sat.)	0.1	110	93.8	95.3	66.9	120.7	-----	-----	-----
Specific Conductance (umho/cm)	1	111	715	716	470	899	2,000[3]	0	0%
pH (S.U.)	0.1	108	8.2	8.3	6.9	8.9	6.5[1,6], 9.0[1,5]	0	0%
Oxidation-Reduction Potential	1	53	392	382	298	543	-----	-----	-----
Alkalinity, Total (mg/l)	7	109	186	186	81	250	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	107	4.2	3.6	2.3	17.2	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	109	21	14	n.d.	141	-----	-----	-----
Chloride (mg/l)	1	108	16	15	7	84	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	58	516	515	328	644	-----	-----	-----
Hardness, Total (mg/l)	0.4	21	277	271	231	379	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	108	-----	0.07	n.d.	0.79	4.7[1,5,8], 1.3[1,7,8]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	109	1.1	0.8	n.d.	5.1	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	108	1058	1.30	n.d.	5.40	10[2,5], 100[3,5]	0	0%
Nitrogen, Total (mg/l)	0.1	108	2.7	2.3	0.3	8.7	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	108	0.31	0.18	0.03	2.40	-----	-----	-----
Suspended Solids, Total (mg/l)	4	109	193	71	13	1,932	-----	-----	-----
Turbidity (NTU)	1	109	158	54	4	1.798	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	10	-----	n.d.	n.d.	60	750[9], 87[10], 200[2]	0	0%
Antimony, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	2.0	88[9], 30[10], 6[2]	0	0%
Arsenic, Dissolved (ug/l)	1	19	-----	2	n.d.	5	340[9], 16.7[10,11], 10[2]	0	0%
Barium, Dissolved (ug/l)	5	11	82	74	60	146	2,000[2]	0	0%
Beryllium, Dissolved (ug/l)	2	12	-----	n.d.	n.d.	n.d.	130[5], 5.3[10], 4[2]	0	0%
Cadmium, Dissolved (ug/l)	0.5	24	-----	n.d.	n.d.	3	16[9], 0.49[10], 5[2]	0, 2, 0	0%, 8%, 0%
Chromium, Dissolved (ug/l)	10	26	-----	n.d.	n.d.	n.d.	1,340[9], 174[10], 100[2]	0	0%
Copper, Dissolved (ug/l)	2	23	-----	n.d.	n.d.	n.d.	34[9], 21[10], 1,000[2]	0	0%
Lead, Dissolved (ug/l)	0.5	24	-----	n.d.	n.d.	1.0	188[9], 7.3[10]	0	0%
Mercury, Dissolved (ug/l)	0.05	24	-----	n.d.	n.d.	n.d.	1.4[9]	0	0%
Mercury, Total (ug/l)	0.05	24	-----	n.d.	n.d.	n.d.	0.77[10], 2[2]	0	0%
Nickel, Dissolved (ug/l)	10	24	-----	n.d.	n.d.	n.d.	1,088[9], 121[10]	0	0%
Selenium, Total (ug/l)	1	12	4	4	2	7	20[3,9], 5[10], 50[2]	0, 1, 0	0%, 8%, 0%
Silver, Dissolved (ug/l)	1	23	-----	n.d.	n.d.	1	19[9], 100[2]	0	0%
Thallium, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	n.d.	1,400[5], 6.3[10,11], 2[2]	0	0%
Zinc, Dissolved (ug/l)	10	24	-----	n.d.	n.d.	39	272[9,10], 5,000[2]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	19	-----	n.d.	n.d.	2.20	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	75	-----	n.d.	n.d.	0.34	760[9], 76[10], 2[2]	0	0%
Atrazine, Total (ug/l)[D]	0.05	94	-----	0.44	n.d.	16.2	330[9], 12[10], 3[2]	0, 1, 2	0%, 1%, 2%
Metolachlor, Total (ug/l)[D]	0.05	94	-----	n.d.	n.d.	2.64	390[9], 100[10]	0	0%
Pesticide Scan (ug/l)[E]	0.05	15					-----	-----	-----
Acetochlor, Total (ug/l)			-----	n.d.	n.d.	0.46	-----	-----	-----
Atrazine, Total (ug/l)			-----	n.d.	n.d.	1.00	330[9], 12[10], 3[2]	0	0%
Metolachlor, Total (ug/l)			-----	n.d.	n.d.	0.40	390[9], 100[10]	0	0%

n.d. = Not detected.

[A] Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for the protection of Class I Warmwater Aquatic Life (Nebraska).
- [2] Criteria for the protection of domestic water supply waters.
- [3] Criteria for the protection of agricultural water supply waters.
- [4] Criteria for the protection of commerce and industry waters.
- [5] Daily maximum criterion (monitoring results directly comparable to criterion).
- [6] Daily minimum criterion (monitoring results directly comparable to criterion).
- [7] 30-day average criterion (monitoring results not directly comparable to criterion).
- [8] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- [9] Acute criterion for aquatic life.
- [10] Chronic criterion for aquatic life.
- [11] Criterion for the protection of human health.

Note: Some of Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] Immunoassay analysis.

[E] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

Plate 410. Summary of water quality conditions monitored in the Missouri River at Nebraska City, Nebraska (i.e., site MORRR0563) during the 5-year period 2005 through 2009.

	Monitoring Results						Water Quality Standards Attainment		
Parameter	**Detection Limit**[A]	**No. of Obs.**	**Mean**[B]	**Median**	**Min.**	**Max.**	**State WQS Criteria**[C]	**No. of WQS Exceedances**	**Percent WQS Exceedance**
Streamflow (cfs)	1	79	34,432	33,750	16,000	117,000	-----	-----	-----
Water Temperature (°C)	0.1	77	15.3	16.5	-0.1	28.2	32[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	76	9.4	8.7	5.4	14.7	5[1,6]	0	0%
Dissolved Oxygen (% Sat.)	0.1	76	92.1	93.3	68.5	104.4	-----	-----	-----
Specific Conductance (umho/cm)	1	77	696	705	472	862	2,000[3]	0	0%
pH (S.U.)	0.1	76	8.2	8.3	7.5	8.7	6.5[1,6], 9.0[1,5]	0	0%
Oxidation-Reduction Potential	1	33	390	377	264	535	-----	-----	-----
Alkalinity, Total (mg/l)	7	79	188	190	130	242	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	44	4.5	3.9	2.0	17.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	79	24	18	n.d.	137	-----	-----	-----
Chloride (mg/l)	1	79	25	25	8	48	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	58	484	491	318	610	-----	-----	-----
Hardness, Total (mg/l)	0.4	15	263	265	215	311	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	79	-----	0.08	n.d.	0.82	4.7 [1,5,8], 1.3 [1,7,8]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	79	1.4	1.1	0.6	5.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	78	1.71	1.60	0.04	4.00	10[2,5], 100[3,5]	0	0%
Nitrogen, Total (mg/l)	0.1	78	3.1	2.9	0.8	8.7	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	79	0.41	0.30	0.09	2.60	-----	-----	-----
Suspended Solids, Total (mg/l)	4	79	215	97	4	1,888	-----	-----	-----
Turbidity (NTU)	1	75	131	60	5	693	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	10	-----	n.d.	n.d.	50	750[9], 87[10], 200[2]	0	0%
Antimony, Dissolved (ug/l)	0.5	114	-----	n.d.	n.d.	1.0	88[9], 30[10], 6[2]	0	0%
Arsenic, Dissolved (ug/l)	1	12	4	4	2	5	340[9], 16.7[10,11], 10[2]	0	0%
Barium, Dissolved (ug/l)	5	11	102	105	73	135	2,000[2]	0	0%
Beryllium, Dissolved (ug/l)	2	12	-----	n.d.	n.d.	n.d.	130[5], 5.3[10], 4[2]	0	0%
Cadmium, Dissolved (ug/l)	0.5	19	-----	n.d.	n.d.	n.d.	15[9], 0.48[10], 5[2]	0	0%
Chromium, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	1,315[9], 171[10], 100[2]	0	0%
Copper, Dissolved (ug/l)	2	18	-----	n.d.	n.d.	3	34[9], 21[10], 1,000[2]	0	0%
Lead, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	n.d.	183[9], 7.1[10]	0	0%
Mercury, Dissolved (ug/l)	0.05	19	-----	n.d.	n.d.	n.d.	1.4[9]	0	0%
Mercury, Total (ug/l)	0.05	19	-----	n.d.	n.d.	n.d.	0.77[10], 2[2]	0	0%
Nickel, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	1,068[9], 119[10]	0	0%
Selenium, Total (ug/l)	1	14	4	4	2	5	20[3,9], 5[10], 50[2]	0	0%
Silver, Dissolved (ug/l)	1	18	-----	n.d.	n.d.	n.d.	18[9], 100[2]	0	0%
Thallium, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	n.d.	1,400[5], 6.3[10,11], 2[2]	0	0%
Zinc, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	72	268[9,10], 5,000[2]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	19	-----	n.d.	n.d.	2.50	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	45	-----	n.d.	n.d.	0.30	760[9], 76[10], 2[2]	0	0%
Atrazine, Total (ug/l)[D]	0.05	65	-----	n.d.	n.d.	4.20	330[9], 12[10], 3[2]	0	0%
Metolachlor, Total (ug/l)[D]	0.05	65	-----	n.d.	n.d.	2.40	390[9], 100[10]	0	0%
Pesticide Scan (ug/l)[E]	0.05	12					-----	-----	-----
Acetochlor, Total (ug/l)			-----	n.d.	n.d.	0.54	-----	-----	-----
Atrazine, Total (ug/l)			-----	n.d.	n.d.	1.20	330[9], 12[10], 3[2]	0	0%
Metolachlor, Total (ug/l)			-----	n.d.	n.d.	0.57	390[9], 100[10]	0	0%

n.d. = Not detected.

[A] Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Class I Warmwater Aquatic Life (Nebraska).
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of agricultural water supply waters.
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (9) Acute criterion for aquatic life.
- (10) Chronic criterion for aquatic life.
- (11) Criterion for the protection of human health.

Note: Some of Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] Immunoassay analysis.

[E] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

Plate 411. Summary of water quality conditions monitored in the Missouri River at Rulo, Nebraska (i.e., site MORRR0498) during the 5-year period 2005 through 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	78	35,917	33,475	17,500	131,000	-----	-----	-----
Water Temperature (°C)	0.1	76	16.1	16.9	0.0	30.6	32[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	75	9.2	8.4	5.2	14.6	5[1,6]	0	0%
Dissolved Oxygen (% Sat.)	0.1	74	92.6	93.7	65.6	111.8	-----	-----	-----
Specific Conductance (umho/cm)	1	76	694	708	384	820	2,000[3]	0	0%
pH (S.U.)	0.1	75	8.2	8.2	7.5	8.6	6.5[1,6], 9.0[1,5]	0	0%
Oxidation-Reduction Potential	1	35	389	374	295	538	-----	-----	-----
Alkalinity, Total (mg/l)	7	78	187	190	120	240	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	76	4.1	36.6	1.4	13.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	78	19	15	n.d.	99	-----	-----	-----
Chloride (mg/l)	1	77	22	22	7	35	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	57	486	486	320	654	-----	-----	-----
Hardness, Total (mg/l)	0.4	15	262	256	226	331	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	78	-----	0.06	n.d.	0.83	5.7 [1,5,8], 1.5 [1,7,8]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	78	1.2	1.0	0.6	5.0	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	77	1.90	1.80	0.03	4.30	10[2,5], 100[3,5]	0	0%
Nitrogen, Total (mg/l)	0.1	77	3.2	2.9	0.7	8.3	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	78	0.39	0.28	0.10	2.80	-----	-----	-----
Suspended Solids, Total (mg/l)	4	78	206	110	14	2,164	-----	-----	-----
Turbidity (NTU)	1	75	138	70	4	2,125	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	10	-----	n.d	n.d.	2,750	750[9], 87[10], 200[2]	1, 1, 1	10%, 10%, 10%
Antimony, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	1.2	88[9], 30[10], 6[2]	0	0%
Arsenic, Dissolved (ug/l)	1	12	3	3	2	5	340[9], 16.7[10,11], 10[2]	0	0%
Barium, Dissolved (ug/l)	5	11	104	102	70	136	2,000[2]	0	0%
Beryllium, Dissolved (ug/l)	2	12	-----	n.d.	n.d.	n.d.	130[5], 5.3[10], 4[2]	0	0%
Cadmium, Dissolved (ug/l)	0.5	19	-----	n.d.	n.d.	n.d.	15[9], 0.47[10], 5[2]	0	0%
Chromium, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	20	1,279[9], 166[10], 100[2]	0	0%
Copper, Dissolved (ug/l)	2	19	-----	n.d.	n.d.	30	33[9], 20[10], 1,000[2]	0, 1, 0	0%, 5%, 0%
Lead, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	0.6	177[9], 6.9[10]	0	0%
Mercury, Dissolved (ug/l)	0.05	19	-----	n.d.	n.d.	n.d.	1.4[9]	0	0%
Mercury, Total (ug/l)	0.05	18	-----	n.d.	n.d.	n.d.	0.77[10], 2[2]	0	0%
Nickel, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	1,037[9], 15[10]	0	0%
Selenium, Total (ug/l)	1	12	4	4	2	5	20[3,9], 5[10], 50[2]	0	0%
Silver, Dissolved (ug/l)	1	18	-----	n.d.	n.d.	n.d.	17[9], 100[2]	0	0%
Thallium, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	n.d.	1,400[5], 6.3[10,11], 2[2]	0	0%
Zinc, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	41	260[9,10], 5,000[2]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	19	-----	n.d.	n.d.	2.40	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	45	-----	n.d.	n.d.	0.20	760[9], 76[10], 2[2]	0	0%
Atrazine, Total (ug/l)[D]	0.05	64	-----	n.d.	n.d.	5.10	330[9], 12[10], 3[2]	0, 0, 2	0%, 0%, 3%
Metolachlor, Total (ug/l)[D]	0.05	64	-----	n.d.	n.d.	2.00	390[9], 100[10]	0	0%
Pesticide Scan (ug/l)[E]	0.05	12					-----	-----	-----
Acetochlor, Total (ug/l)			-----	n.d.	n.d.	0.70	-----	-----	-----
Atrazine, Total (ug/l)			-----	n.d.	n.d.	4.80	330[9], 12[10], 3[2]	0, 0, 1	0%, 0%, 8%
Metolachlor, Total (ug/l)			-----	n.d.	n.d.	0.45	390[9], 100[10]	0	0%

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

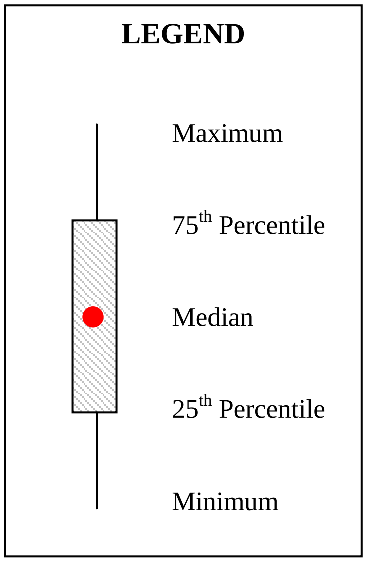
- (1) Criteria for the protection of Class I Warmwater Aquatic Life (Nebraska).
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of agricultural water supply waters.
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (9) Acute criterion for aquatic life.
- (10) Chronic criterion for aquatic life.
- (11) Criterion for the protection of human health.

Note: Some of Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

Plate 412. Distribution plots (i.e., box plots) for selected parameters monitored at locations along the Missouri River from the Gavins Point Dam tailwaters to Rulo, Nebraska during the 5-year period of 2005 through 2009.



Note: Monitoring location refers to the River Mile (RM) along the Missouri River where the monitoring site was located.

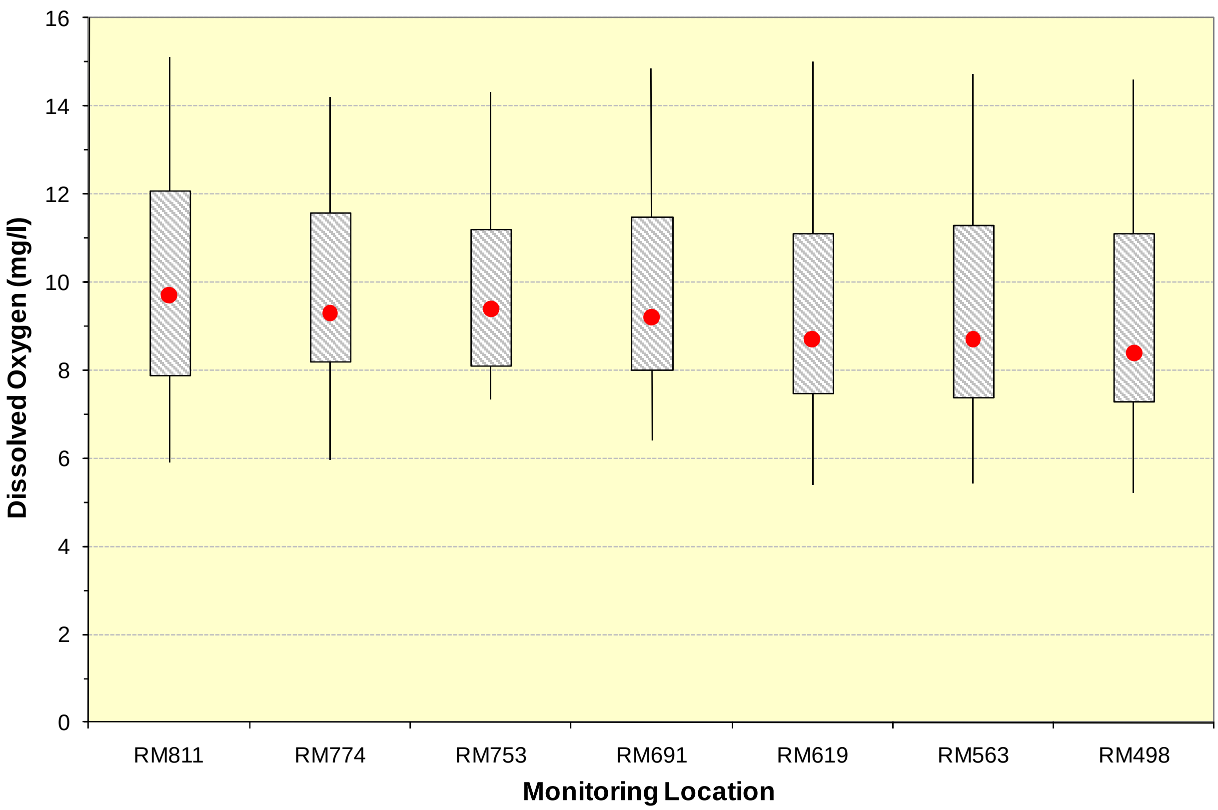
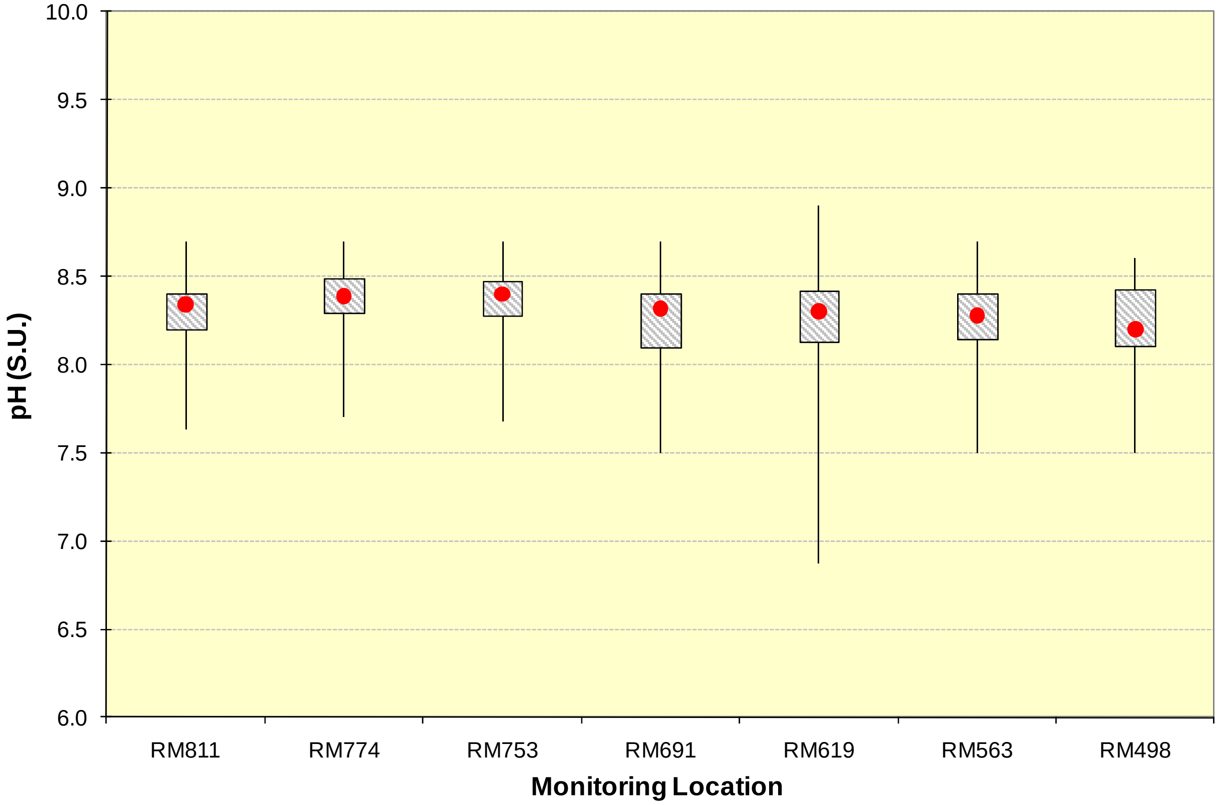


Plate 412. (Continued).



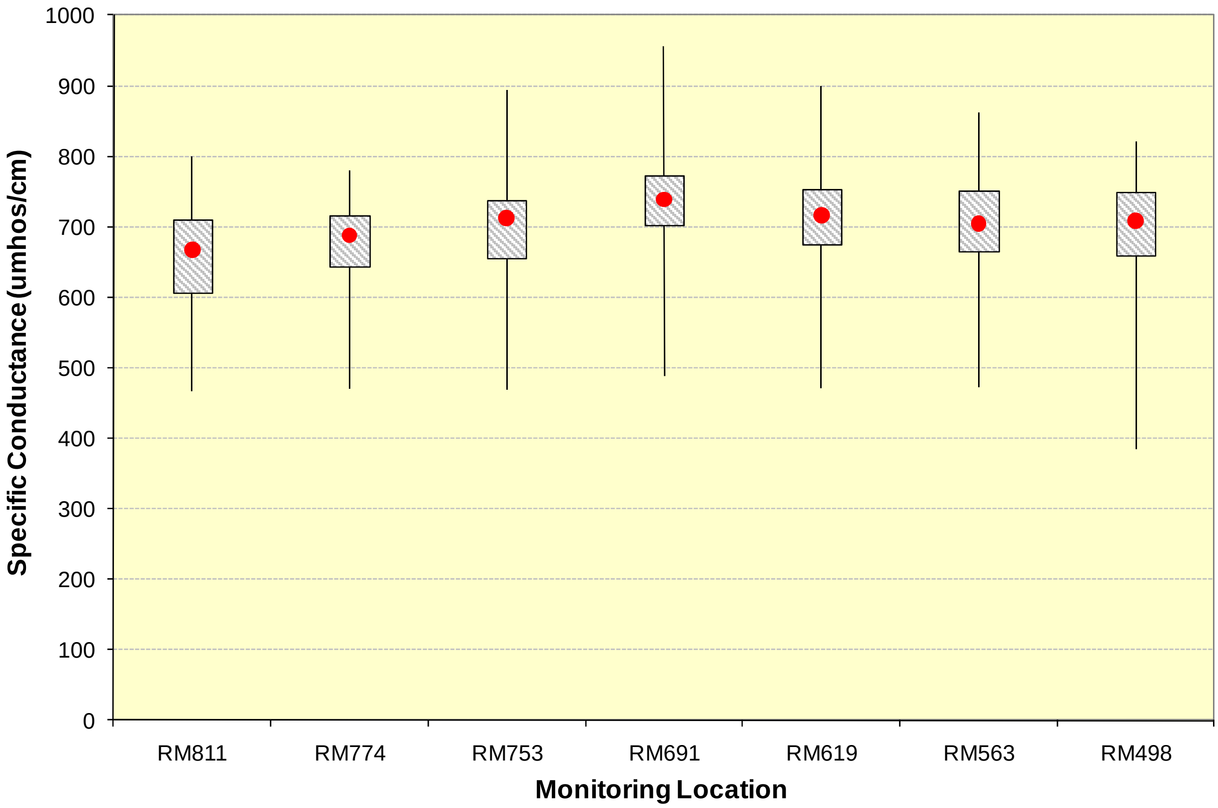
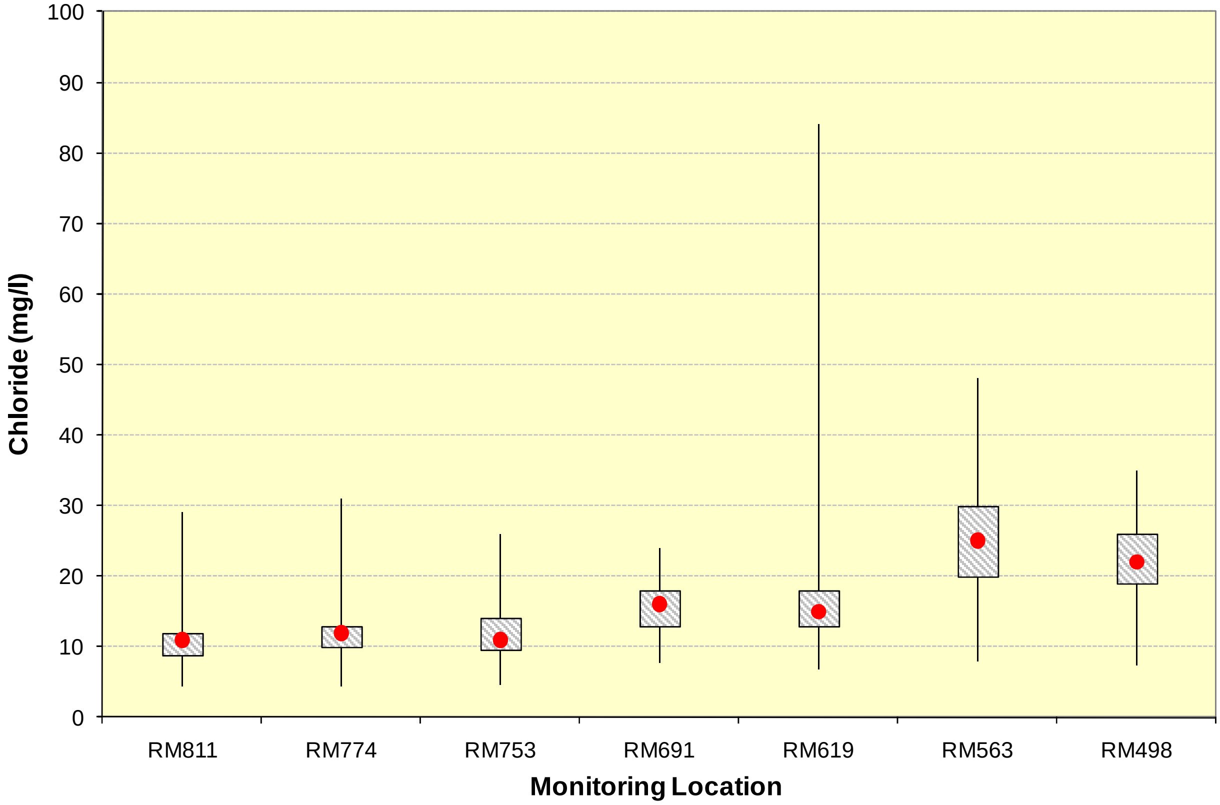


Plate 412. (Continued).



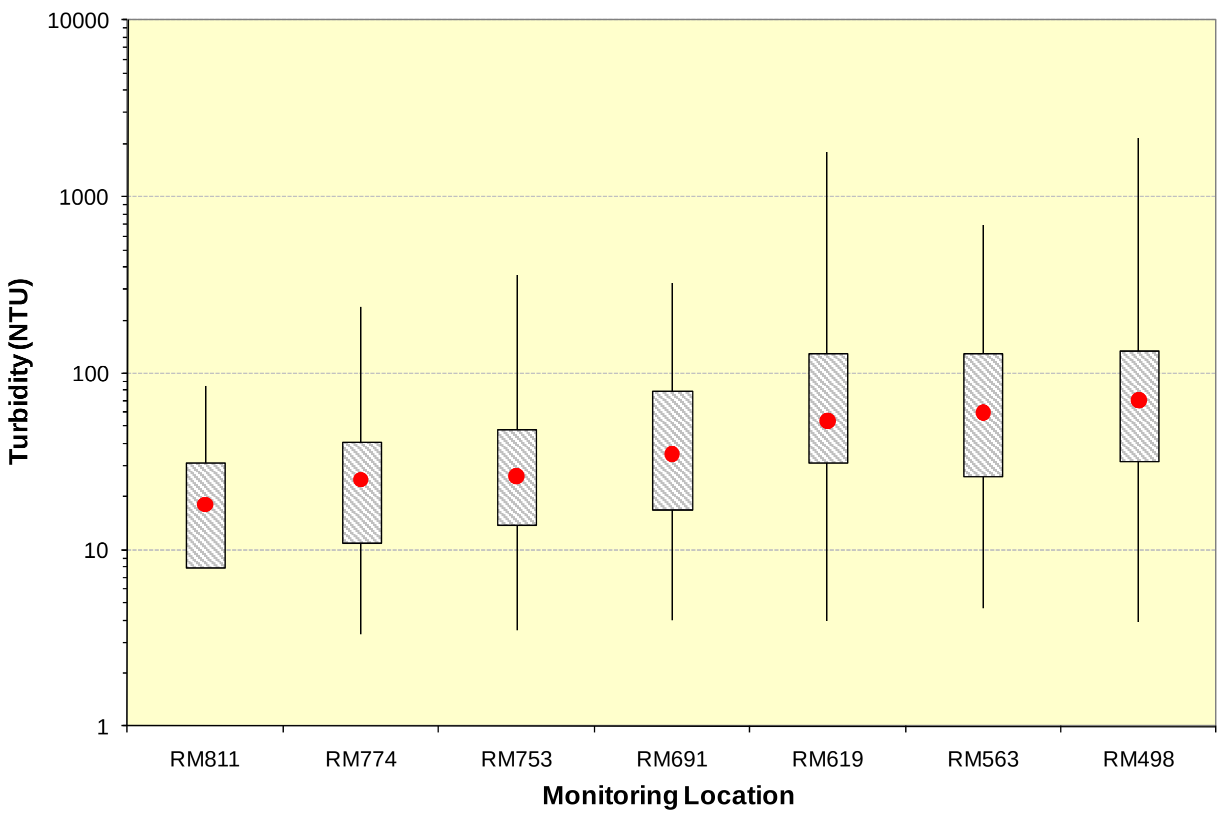
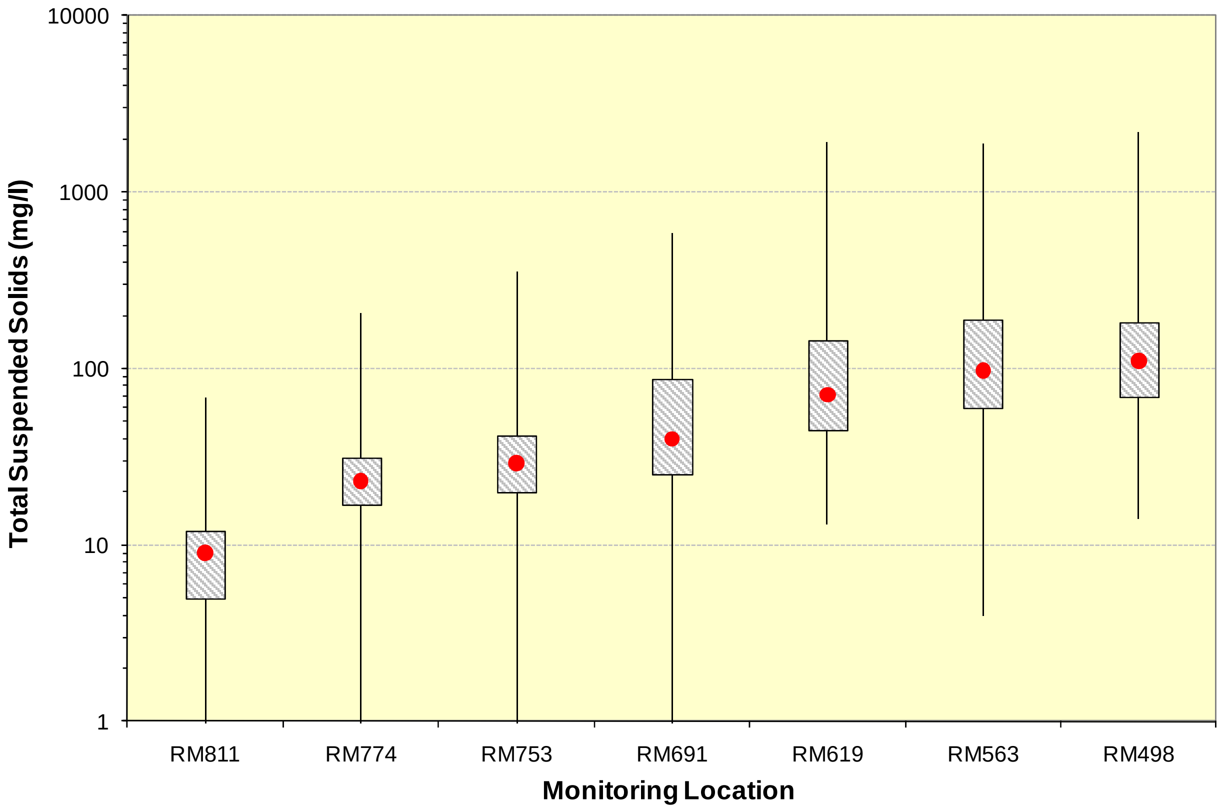


Plate 412. (Continued).



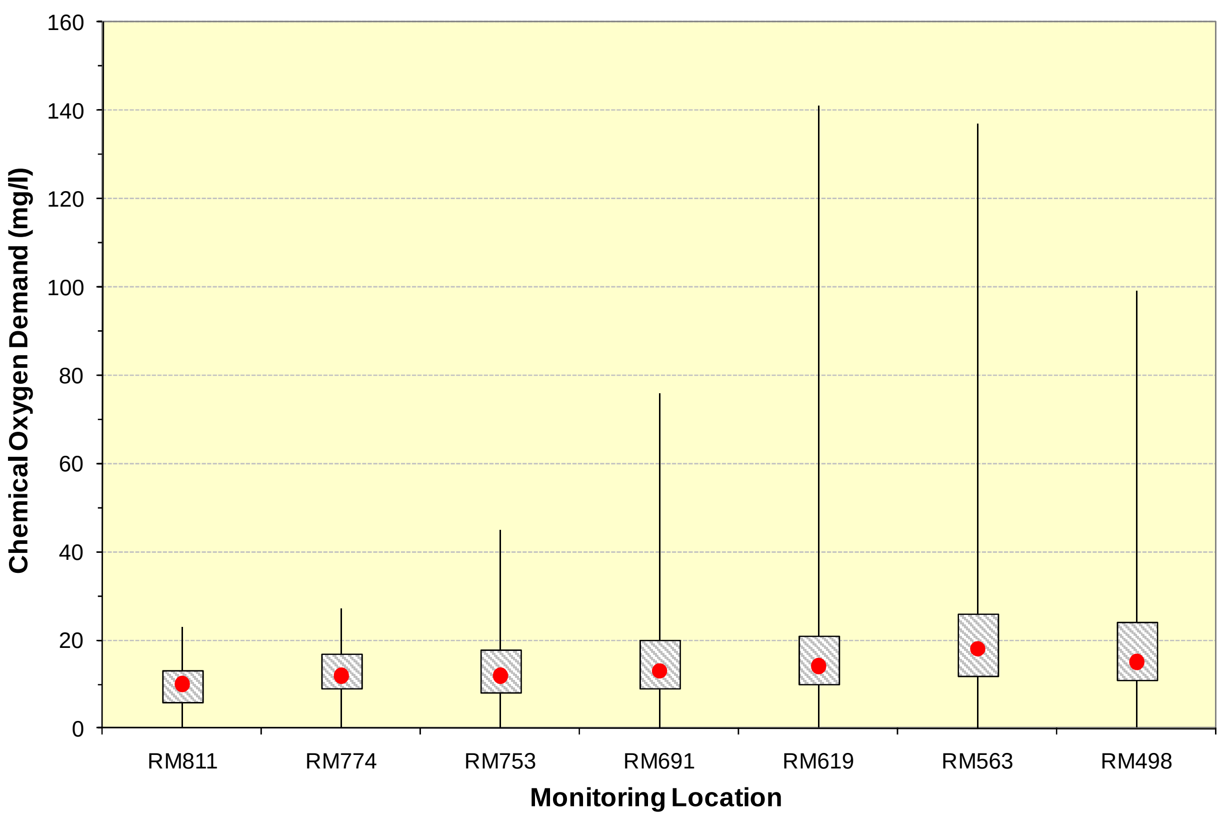
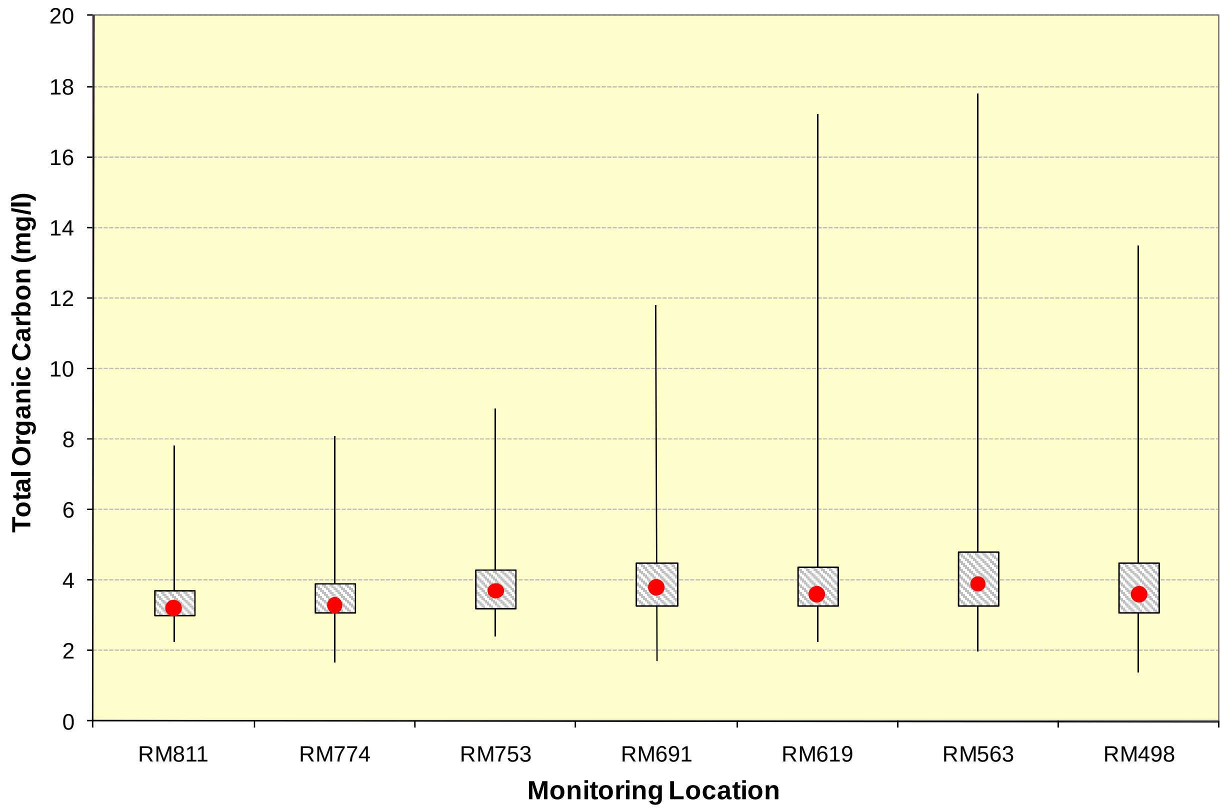


Plate 412. (Continued).



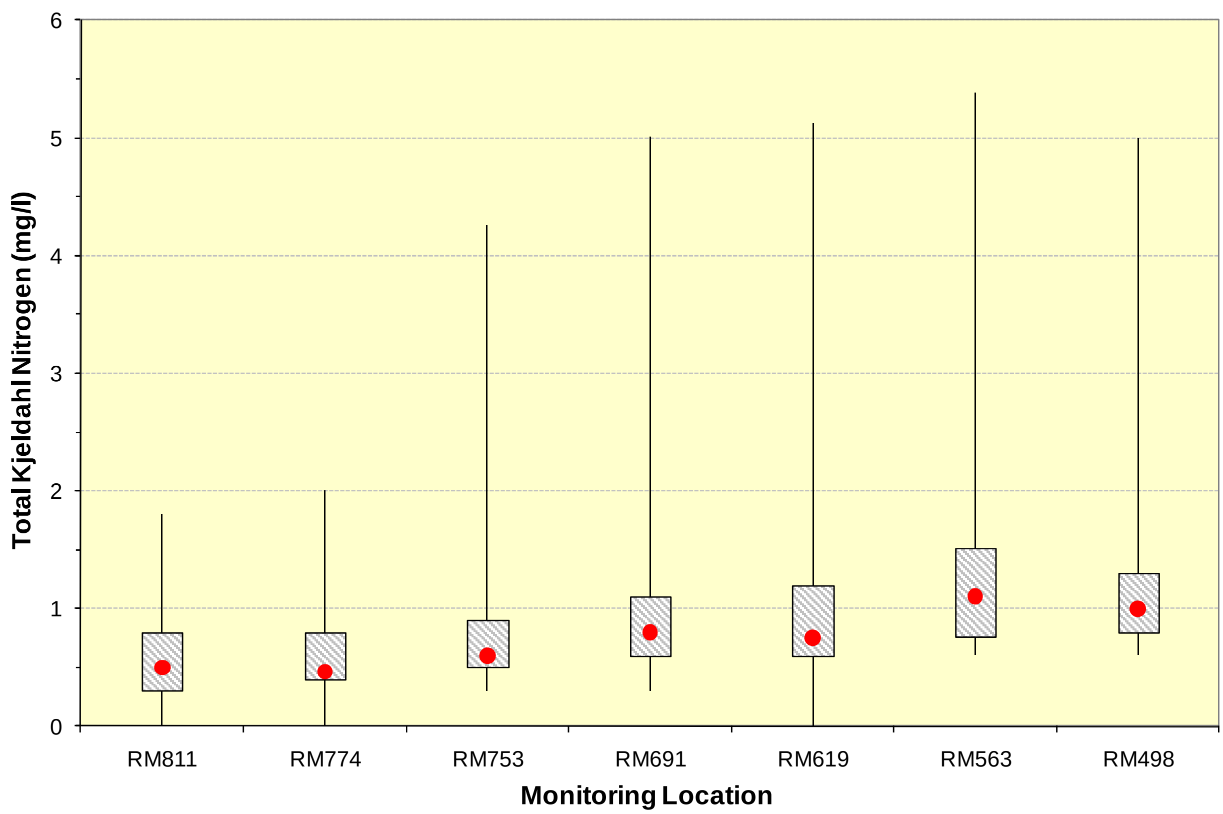
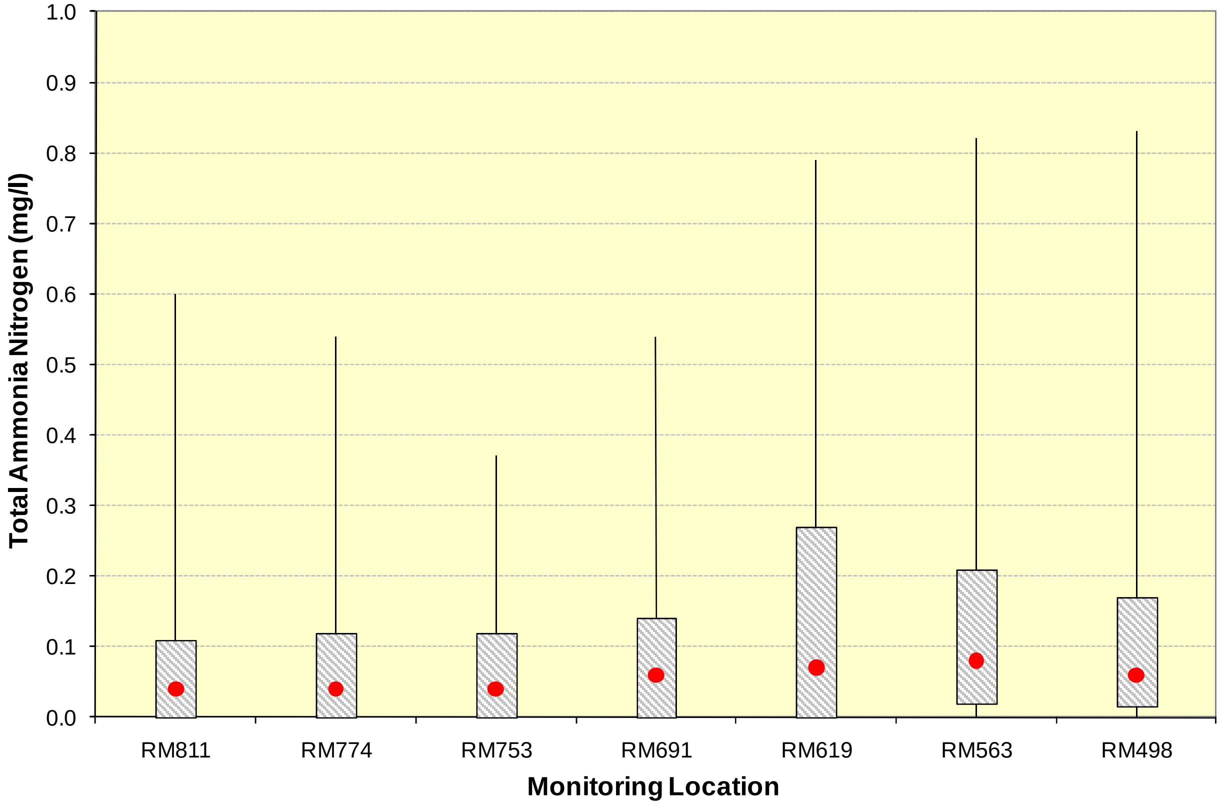


Plate 412. (Continued).



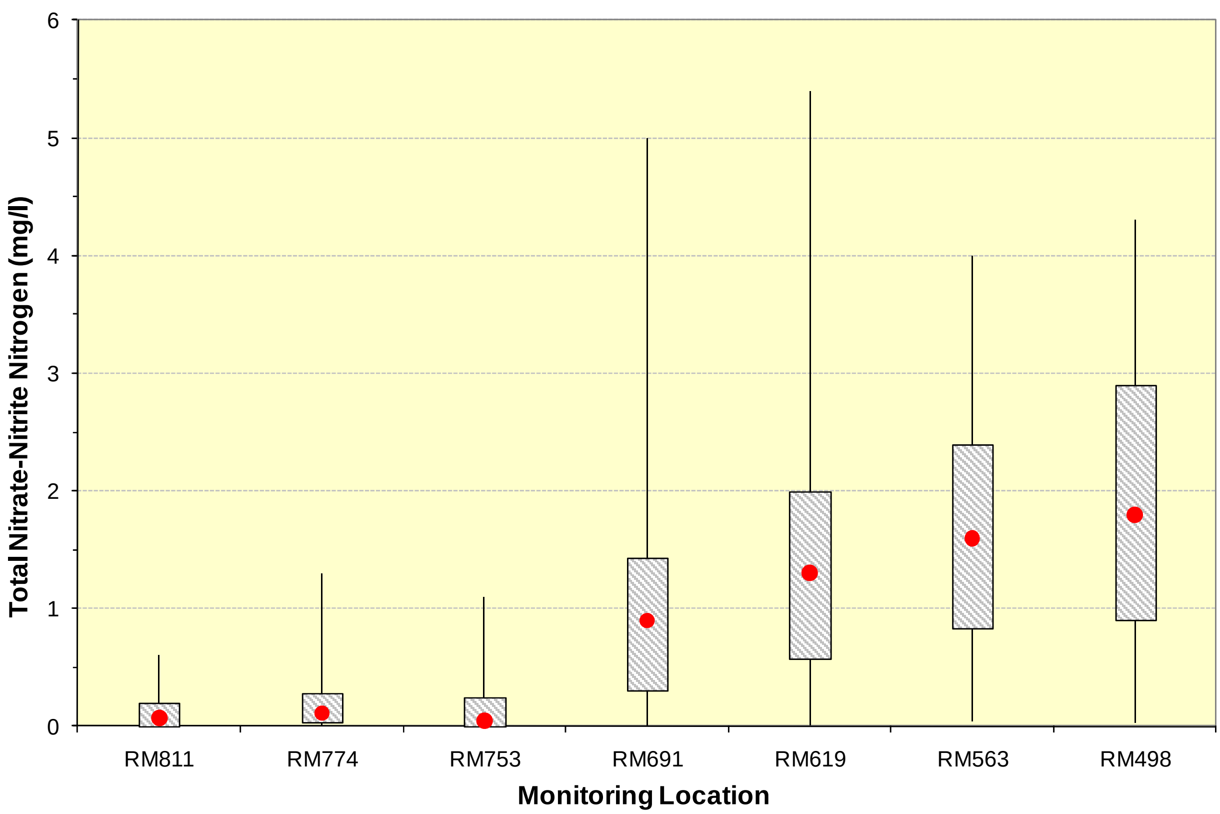


Plate 412. (Continued).

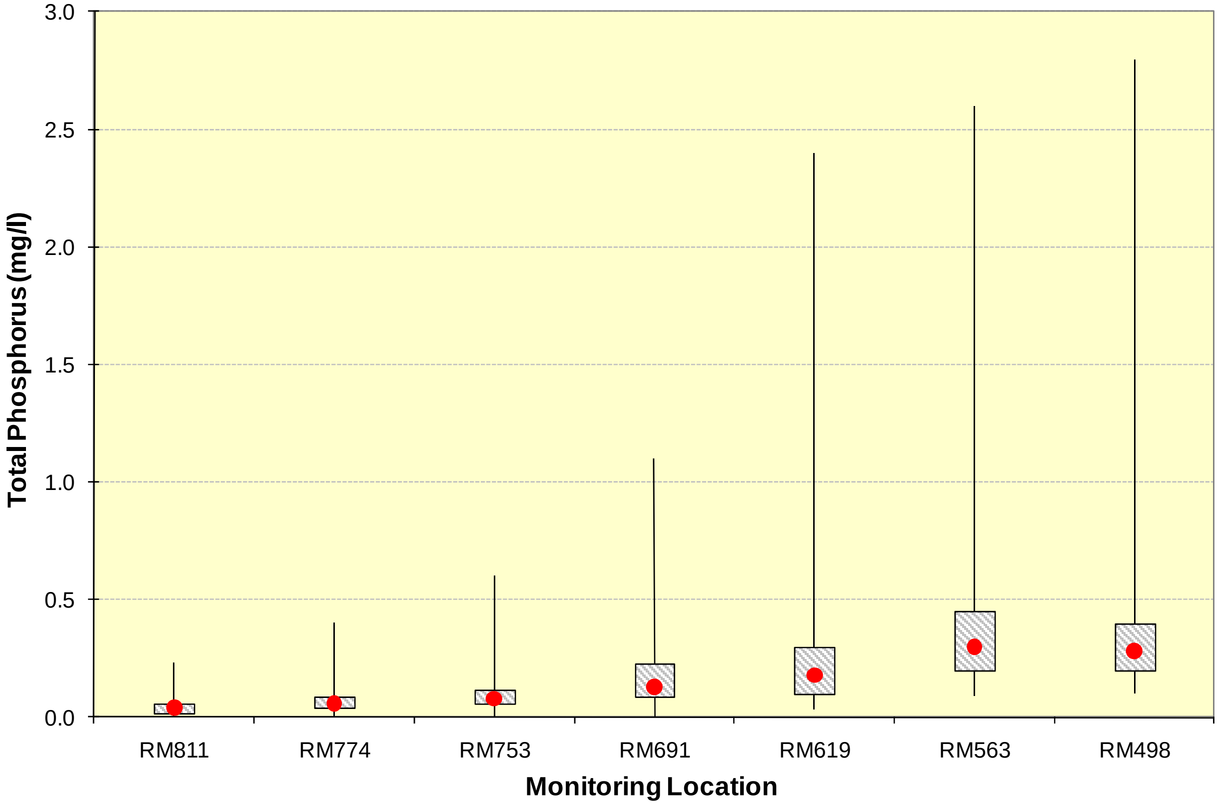


Plate 413. Mean daily water temperatures calculated for the lower Missouri River during 2009 at Gavins Point Dam; Sioux City, IA; Decatur, NE; Omaha, NE; and St. Joseph, MO.

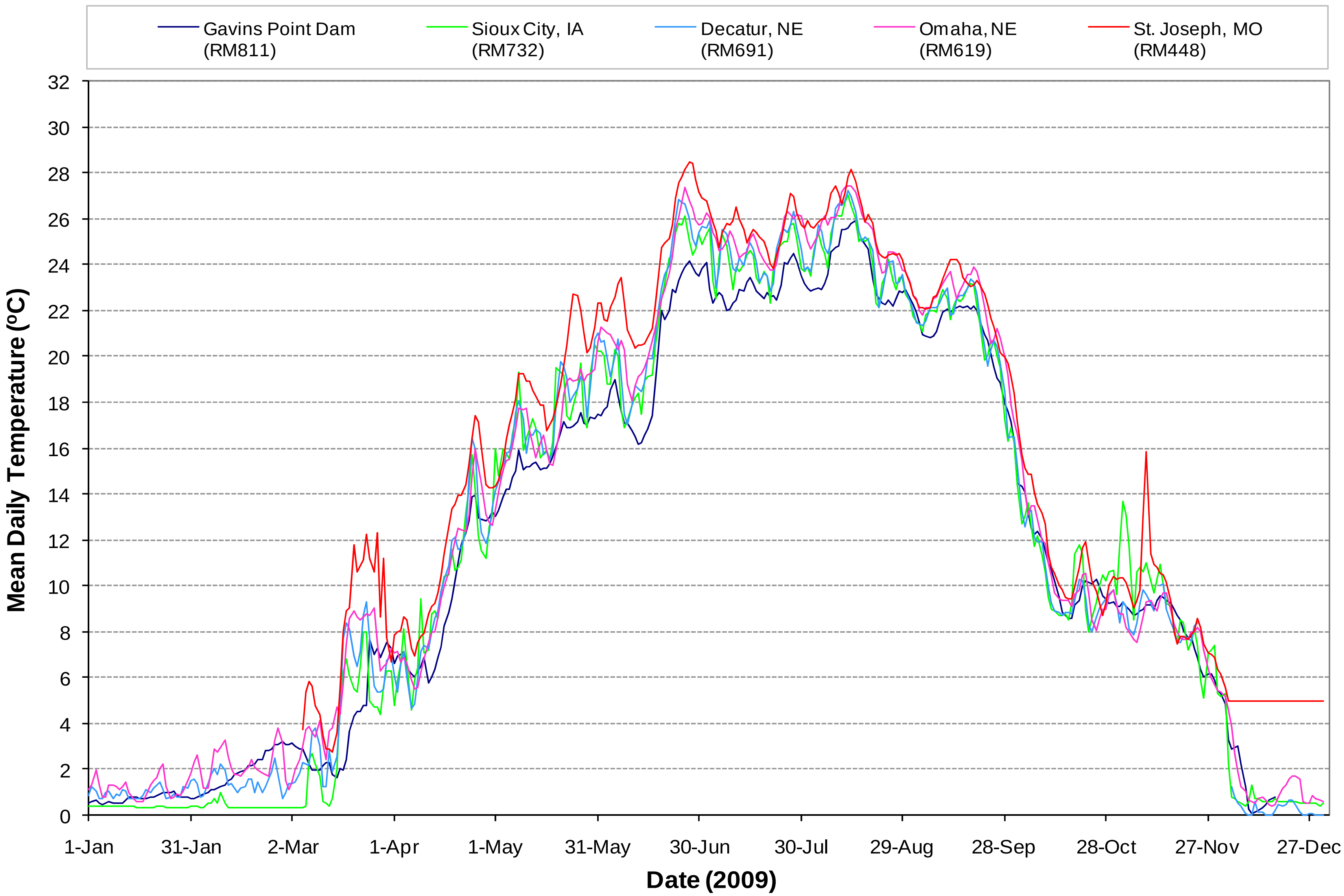


Plate 414. Summary of monthly (May through September) water quality conditions monitored in Lake Audubon (i.e., site AUDLKND1) during 2006 and 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation	1	9	1846.9	1846.9	1846.6	1847.0	-----	-----	-----
Water Temperature (°C)	0.1	152	17.6	18.3	9.6	25.5	29.4(1,2)	0	0%
Dissolved Oxygen (mg/l)	0.1	152	8.5	8.6	1.7	10.6	5.0(1,3)	5	3%
Dissolved Oxygen (% Sat.)	0.1	152	91.5	95.0	19.1	104.3	-----	-----	-----
Specific Conductance (umho/cm)	1	150	917	932	803	969	-----	-----	-----
pH (S.U.)	0.1	152	8.5	8.5	7.7	8.8	6.5(1,3), 9.0(1,2)	0	0%
Oxidation-Reduction Potential (mV)	1	152	358	341	271	477	-----	-----	-----
Secchi Depth (in)	1	9	89	65	48	192	-----	-----	-----
Alkalinity, Total (mg/l)	7	18	207	209	170	220	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	18	4.7	4.8	3.4	6.0	-----	-----	-----
Chloride (mg/l)	1	18	14	15	11	16	-----	-----	-----
Chlorophyll *a* (ug/l) - Field Probe	1	69	-----	6	n.d.	10	-----	-----	-----
Chlorophyll *a* (ug/l) - Lab Determined	1	9	-----	3	n.d.	7	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	18	699	672	590	862	-----	-----	-----
Hardness, Total (mg/l)	0.4	3	270	272	264	275	-----	-----	-----
Iron, Dissolved (ug/l)	40	14	-----	n.d.	n.d.	40	-----	-----	-----
Iron, Total (ug/l)	40	14	206	195	80	383	-----	-----	-----
Manganese, Dissolved (ug/l)	2	14	-----	n.d.	n.d.	4	-----	-----	-----
Manganese, Total (ug/l)	2	14	11	10	n.d.	24	-----	-----	-----
Nitrogen, Total Ammonia (mg/l)	0.02	18	-----	0.04	n.d.	0.13	3.2 (1,2,4), 1.0 (1,4,5)	0	0%
Nitrogen, Total Kjeldahl (mg/l)	0.1	18	0.5	0.4	n.d.	1.3	-----	-----	-----
Nitrogen, Total Nitrate-Nitrite (mg/l)	0.02	18	-----	n.d.	n.d.	0.10	-----	-----	-----
Nitrogen, Total (mg/l)	0.1	18	0.5	0.5	n.d.	1.3	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	18	-----	n.d.	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	18	-----	0.03	n.d.	0.35	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	18	-----	n.d.	n.d.	0.02	-----	-----	-----
Sulfate (mg/l)	1	18	294	276	266	330	-----	-----	-----
Suspended Solids, Total (mg/l)	4	18	-----	n.d.	n.d.	8	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	1	0.7	0.7	0.7	0.7	5.6(8)	0	0%
Arsenic, Dissolved (ug/l)	1	2	3	3	2	3	340(6), 150(7), 10(8)	0	0%
Beryllium, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	4(8)	0	0%
Cadmium, Dissolved (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	5.9(6), 0.57(7), 5(8)	0	0%
Chromium, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	4,092(6), 196(7), 100(8)	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	35.9(6), 22(7), 1,000(8)	0	0%
Lead, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	292(6), 11(7), 15(8)	0	0%
Nickel, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	1,094(6), 122(7), 100(8)	0	0%
Selenium, Total (ug/l)	1	1	-----	n.d.	n.d.	n.d.	20(6), 5(7), 50(8)	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	14.7(6)	0	0%
Zinc, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	280(6,7), 7,400(8)	0	0%
Pesticide Scan (ug/l)(D)	0.05	2	-----	n.d.	n.d.	n.d.	-----	-----	-----
Microcystin	0.2	9	-----	n.d.	n.d.	0.2	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for Class 2 lakes.
(2) Daily maximum criterion (monitoring results directly comparable to criterion).
(3) Daily minimum criterion (monitoring results directly comparable to criterion).
(4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(5) 30-day average criterion (monitoring results not directly comparable to criterion).
(6) Acute criterion for aquatic life.
(7) Chronic criterion for aquatic life.
(8) Human health criterion for surface waters.

Note: Some of North Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

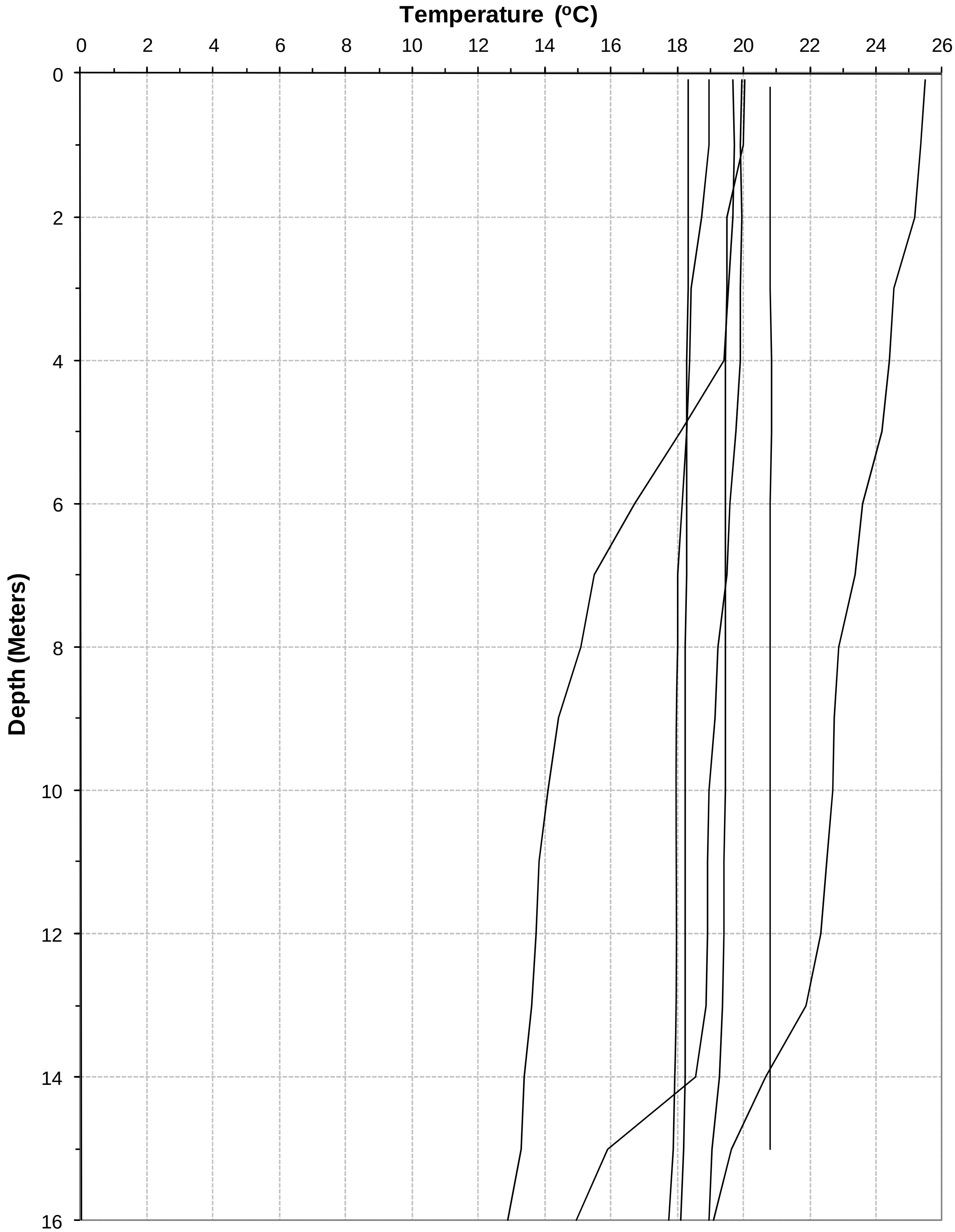


Plate 415. Temperature depth profiles for Lake Audubon generated from data collected at the near-dam, deepwater ambient monitoring site during the summer months of 2006 and 2009.

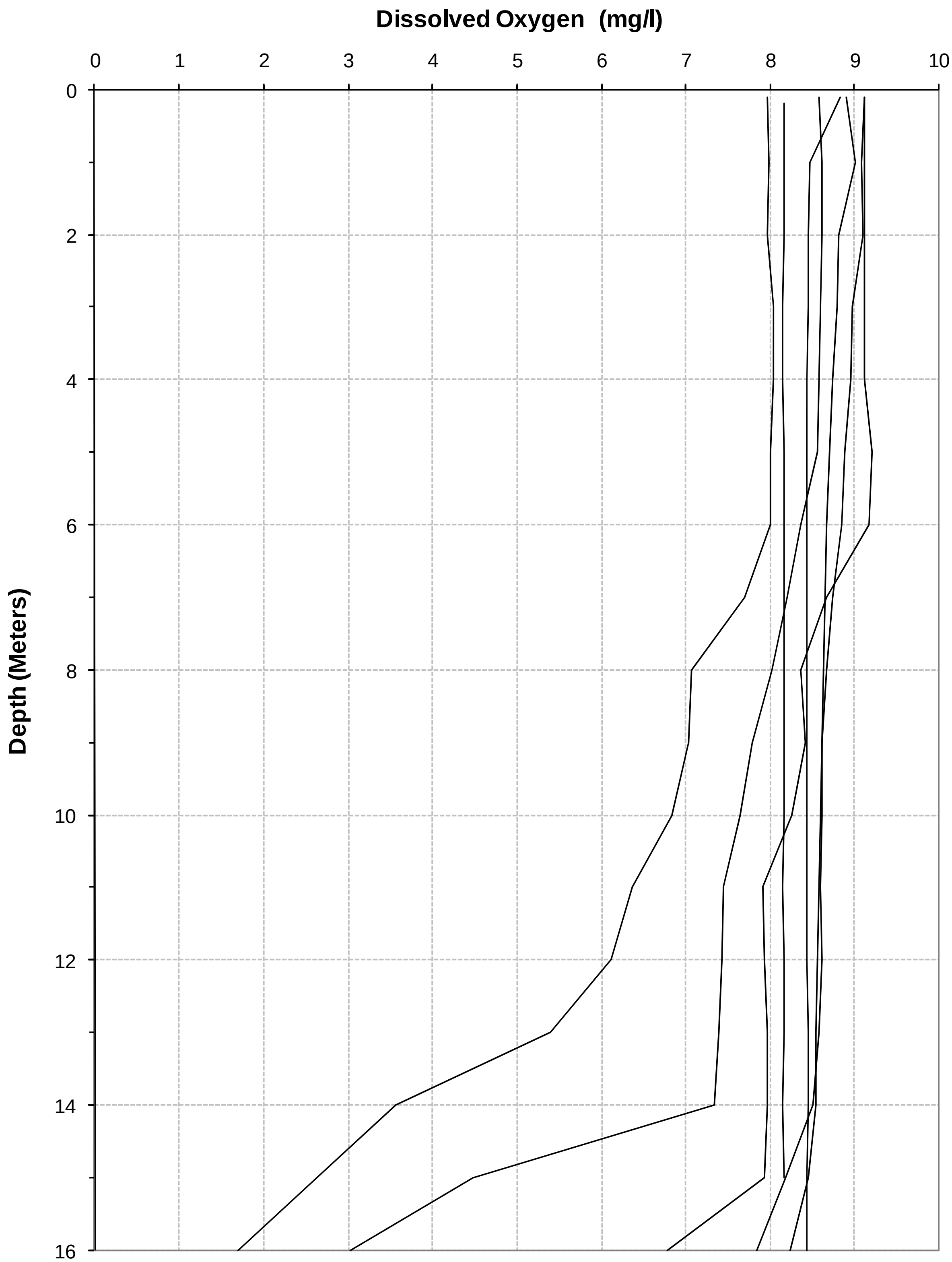


Plate 416. Dissolved oxygen depth profiles for Lake Audubon generated from data collected at the near-dam, deepwater ambient monitoring site during the summer months of 2006 and 2009.

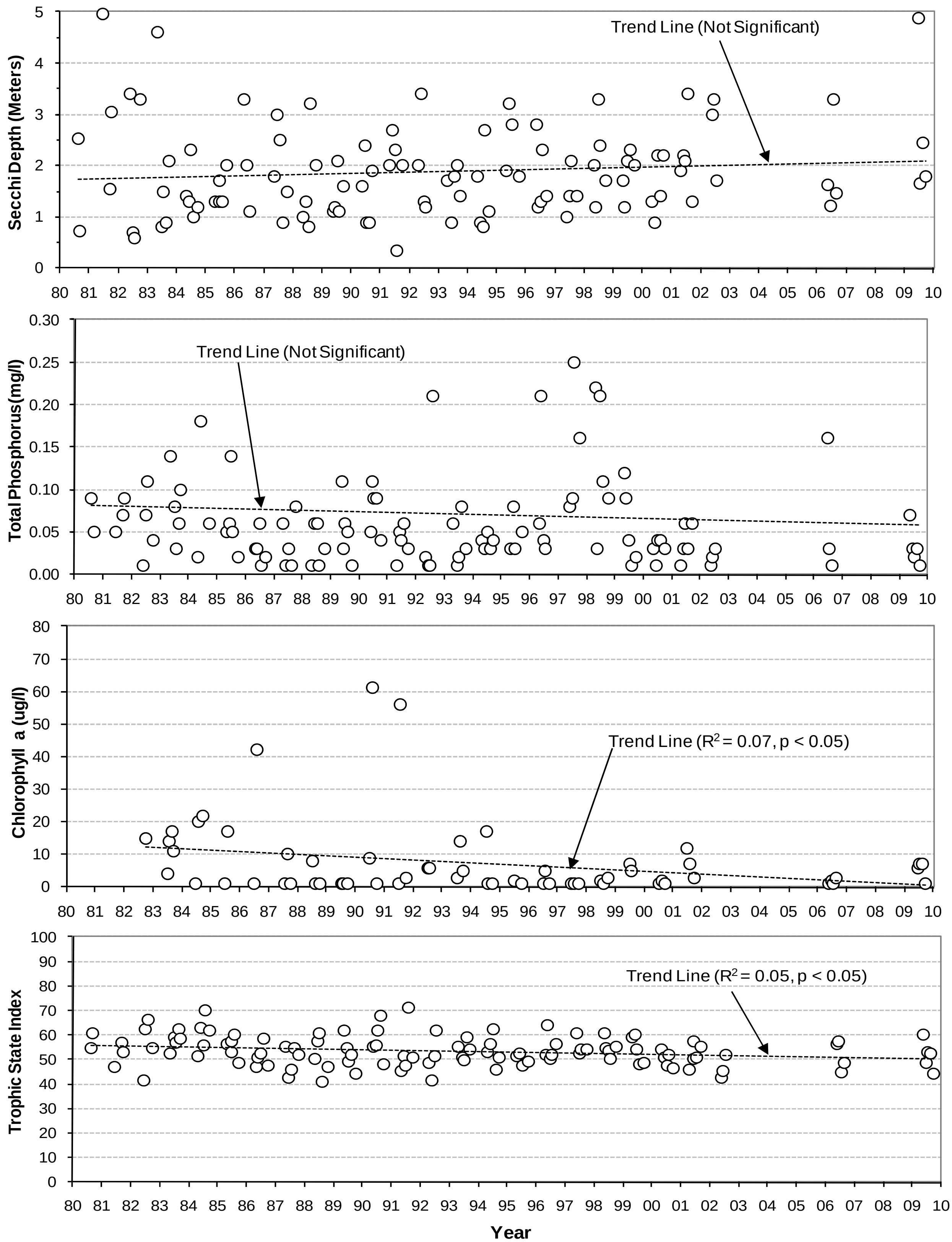


Plate 417. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Lake Audubon at the near-dam, ambient site over the 30-year period of 1980 through 2009.

Plate 418. Summary of monthly (June through September) water quality conditions monitored in Lake Pocasse (i.e., site POCLKND1) during 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation	1	4	1616.9	1617.0	1616.6	1617.0	-----	-----	-----
Water Temperature (°C)	0.1	17	20.6	19.7	19.1	22.8	27(1,4)	0	0%
Dissolved Oxygen (mg/l)	0.1	17	8.5	8.6	8.2	8.7	5.0(1,5)	0	0%
Dissolved Oxygen (% Sat.)	0.1	17	97.9	96.7	93.0	104.5	-----	-----	-----
Specific Conductance (umho/cm)	1	17	604	568	502	717	-----	-----	-----
pH (S.U.)	0.1	17	8.5	8.6	8.2	8.9	6.5(1,2,5), 9.0(1,2)	0	0%
Oxidation-Reduction Potential (mV)	1	17	385	382	321	454	-----	-----	-----
Secchi Depth (in)	1	4	24	23	17	34	-----	-----	-----
Alkalinity, Total (mg/l)	7	6	206	212	152	241	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	6	13.3	15.9	1.1	20.9	-----	-----	-----
Chloride (mg/l)	1	6	16	17	12	18	-----	-----	-----
Chlorophyll *a* (ug/l) - Field Probe	1	17	77	83	12	164	-----	-----	-----
Chlorophyll *a* (ug/l) - Lab Determined	1	4	70	75	12	118	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	6	463	485	366	524	-----	-----	-----
Hardness, Total (mg/l)	0.4	1	213	213	213	213	-----	-----	-----
Iron, Dissolved (ug/l)	40	2	15	15	10	20	-----	-----	-----
Iron, Total (ug/l)	40	2	460	460	340	580	-----	-----	-----
Manganese, Dissolved (ug/l)	2	2	575	575	540	610	-----	-----	-----
Manganese, Total (ug/l)	2	2	605	605	550	660	-----	-----	-----
Nitrogen, Total Ammonia (mg/l)	0.02	6	0.10	0.11	0.03	0.13	2.7 (1,2,4), 0.61 (1,4,5)	0	0%
Nitrogen, Total Kjeldahl (mg/l)	0.1	6	2.4	2.2	1.6	3.2	-----	-----	-----
Nitrogen, Total Nitrate-Nitrite (mg/l)	0.02	6	0.06	0.04	n.d.	0.20	-----	-----	-----
Nitrogen, Total (mg/l)	0.1	6	2.4	2.2	1.8	3.2	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	6	1.25	1.24	1.00	1.48	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	6	1.32	1.32	1.00	1.60	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	6	1.07	1.10	0.80	1.30	-----	-----	-----
Sulfate (mg/l)	1	6	105	109	84	115	-----	-----	-----
Suspended Solids, Total (mg/l)	4	6	15	16	4	24	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	1	3.8	3.8	3.8	3.8	5.6(8)	0	0%
Arsenic, Dissolved (ug/l)	1	1	12	12	12	12	340(6), 150(7)	0	0%
Beryllium, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	4(8)	0	0%
Cadmium, Dissolved (ug/l)	0.2	1	-----	n.d.	n.d.	n.d.	4.2(6), 0.42(7)	0	0%
Chromium, Dissolved (ug/l)	10	1	-----	n.d.	n.d.	n.d.	1,058(6), 138(7)	0	0%
Copper, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	27(6), 17(7)	0	0%
Lead, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	146(6), 5.7(7)	0	0%
Nickel, Dissolved (ug/l)	10	1	-----	n.d.	n.d.	n.d.	888(6), 99(7)	0	0%
Selenium, Total (ug/l)	1	1	1	1	1	1	4.6(7), 170(8)	0	0%
Silver, Dissolved (ug/l)	1	1	-----	n.d.	n.d.	n.d.	11(6)	0	0%
Thallium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	-----	-----	-----
Zinc, Dissolved (ug/l)	10	1	-----	n.d.	n.d.	n.d.	22(6,7)	0	0%
Microcystin	0.2	4	-----	0.06	n.d.	0.14	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of warmwater permanent fish life propagation waters.
(2) Daily maximum criterion (monitoring results directly comparable to criterion).
(3) Daily minimum criterion (monitoring results directly comparable to criterion).
(4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(5) 30-day average criterion (monitoring results not directly comparable to criterion).
(6) Acute criterion for aquatic life.
(7) Chronic criterion for aquatic life.
(8) Human health criterion for surface waters.

Note: Some of South Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

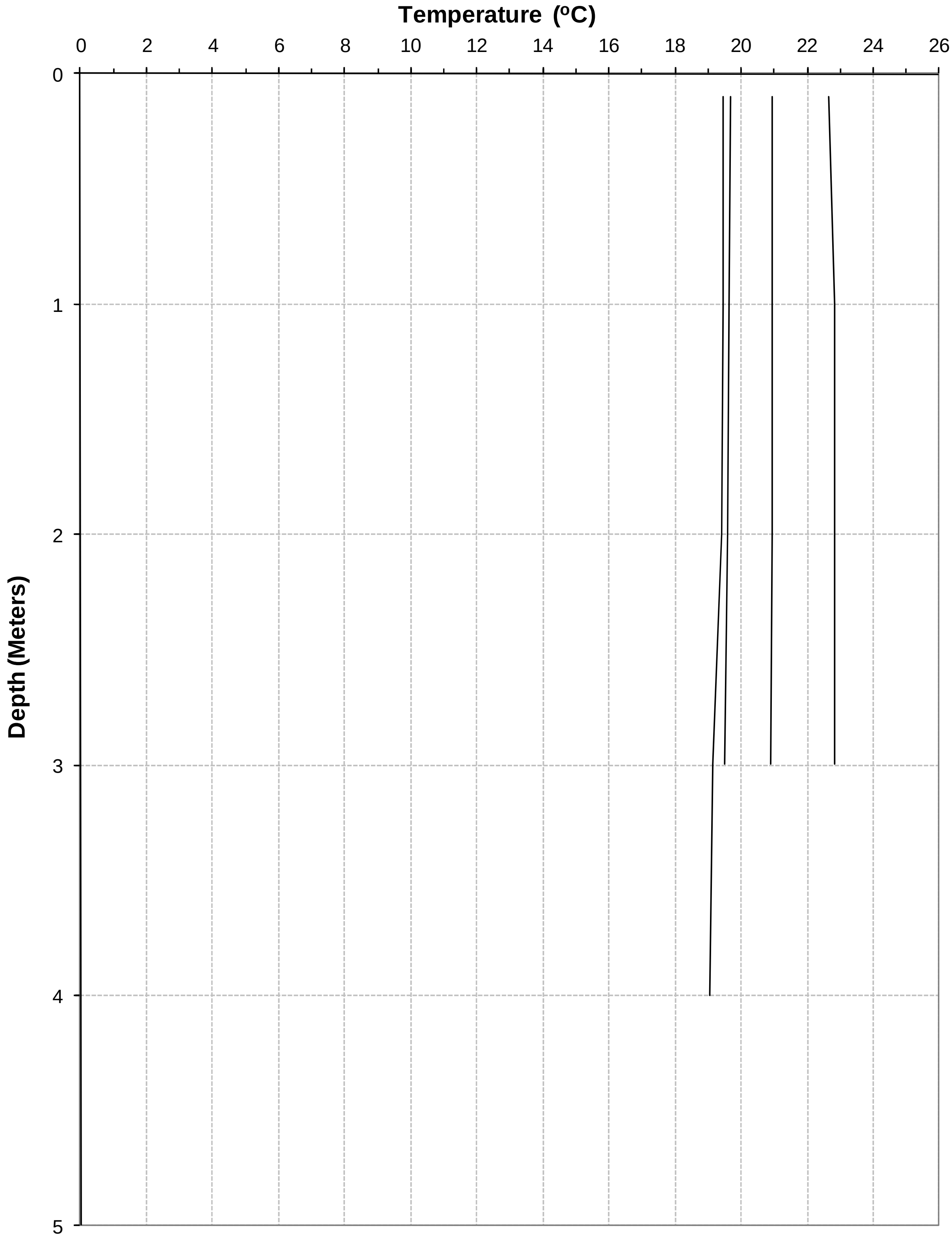


Plate 419. Temperature depth profiles for Lake Pocasse generated from data collected at the near-dam, deepwater ambient monitoring site during the summer months of 2009.

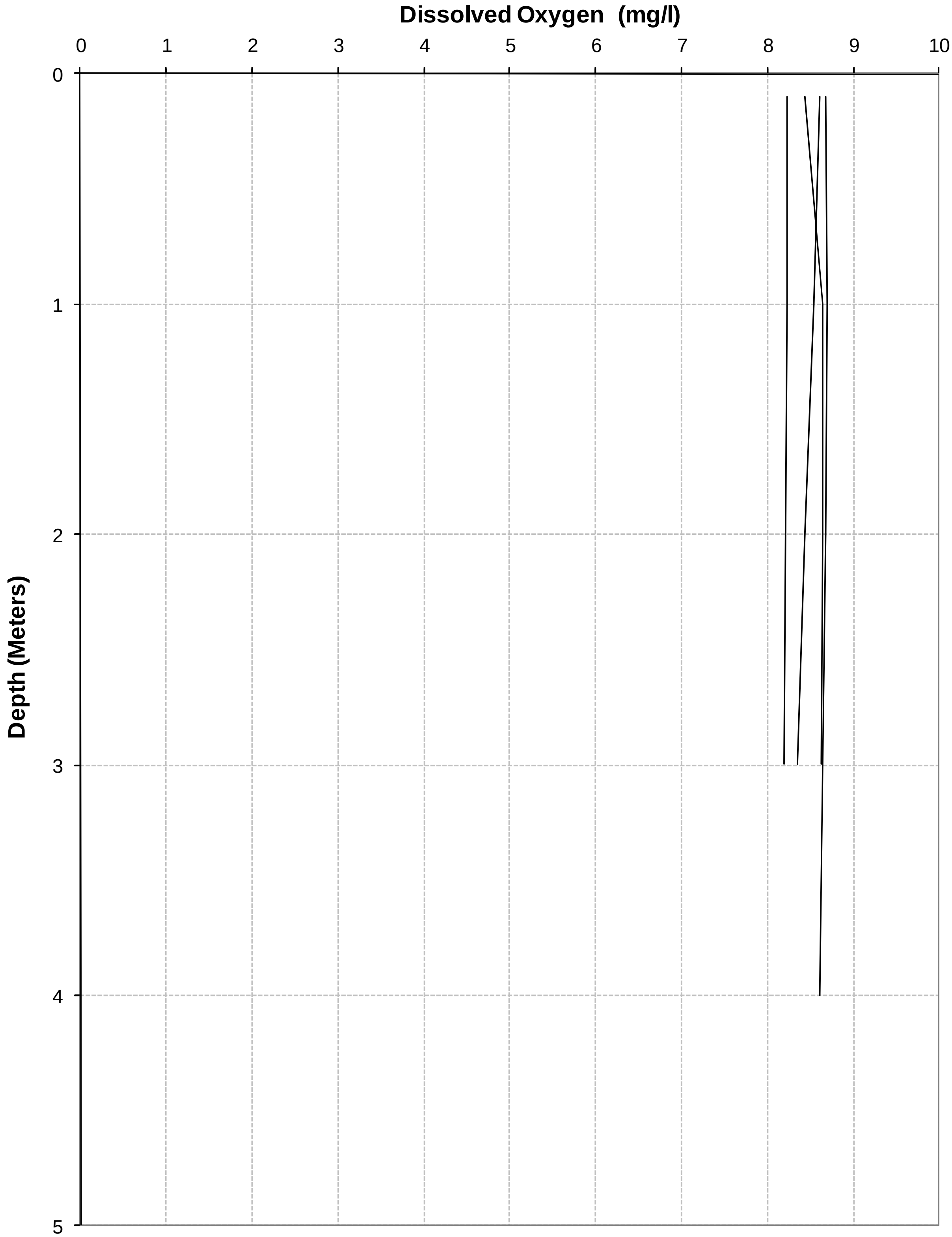


Plate 420. Dissolved oxygen depth profiles for Lake Pocasse generated from data collected at the near-dam, deepwater ambient monitoring site during the summer months of 2009.

Plate 421. Summary of monthly (May through September) water quality conditions monitored in Lake Yankton (i.e., site YAKLKND1) during 2006 and 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation	1	8	1167.4	1167.5	1167.2	1167.7	-----	-----	-----
Water Temperature (°C)	0.1	58	19.2	18.5	14.2	26.1	27[1,2,5], 29[1,2,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	58	5.9	7.7	0.3	11.8	5[1,2,7]	22	38%
Dissolved Oxygen (% Sat.)	0.1	58	67.3	86.1	2.7	137.8	-----	-----	-----
Specific Conductance (umho/cm)	1	58	1012	1025	874	1191	2,000[4]	0	0%
pH (S.U.)	0.1	58	7.8	7.8	7.2	8.7	6.5[1,3,6], 9.0[1,3,5]	0	0%
Oxidation-Reduction Potential (mV)	1	58	337	350	31	480	-----	-----	-----
Secchi Depth (in)	1	10	45	46	12	67	-----	-----	-----
Alkalinity, Total (mg/l)	7	20	184	191	140	220	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	20	3.5	3.1	1.1	15.9	-----	-----	-----
Chloride (mg/l)	1	20	14	14	12	17	-----	-----	-----
Chlorophyll *a* (ug/l) - Field Probe	1	31	16	14	3	70	-----	-----	-----
Chlorophyll *a* (ug/l) - Lab Determined	1	10	11	6	n.d.	54	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	20	735	736	680	790	-----	-----	-----
Hardness, Total (mg/l)	0.4	3	410	414	401	416	-----	-----	-----
Iron, Dissolved (ug/l)	40	16	-----	n.d.	n.d.	50	-----	-----	-----
Iron, Total (ug/l)	40	16	129	118	40	250	-----	-----	-----
Manganese, Dissolved (ug/l)	2	16	1,215	436	n.d.	6,820	-----	-----	-----
Manganese, Total (ug/l)	2	16	1,432	594	170	6,820	-----	-----	-----
Nitrogen, Total Ammonia (mg/l)	0.02	20	-----	0.07	n.d.	0.48	12.1[1,5,8], 2.4 [1,7,8]	0	0%
Nitrogen, Total Kjeldahl (mg/l)	0.1	20	0.7	0.7	0.3	1.1	-----	-----	-----
Nitrogen, Total Nitrate-Nitrite (mg/l)	0.02	20	-----	n.d.	n.d.	0.19	10[3,5], 100[4,5]	0	0%
Nitrogen, Total (mg/l)	0.1	20	0.7	0.8	0.3	1.1	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	20	-----	n.d.	n.d.	0.02	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	20	0.05	0.03	n.d.	0.22	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	20	-----	n.d.	n.d.	0.15	-----	-----	-----
Sulfate (mg/l)	1	18	377	374	338	420	-----	-----	-----
Suspended Solids, Total (mg/l)	4	20	-----	2	n.d.	12	158[1,5], 90[1,7]	0	0%
Antimony, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	88[9], 30[10], 6[11]	0	0%
Arsenic, Dissolved (ug/l)	1	1	2	2	2	2	340[9], 16.7[10], 10[11]	0	0%
Beryllium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	130[9], 5.3[10], 4[11]	0	0%
Cadmium, Dissolved (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	25.4[9], 0.7[10], 5[11]	0	0%
Chromium, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	2,026[9], 263[10], 100[11]	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	55.3[9], 32.3[10], 1,000[11]	0	0%
Lead, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	316[9], 12.3[10], 15[11]	0	0%
Nickel, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	1,668[9], 185[10], 100[11]	0	0%
Selenium, Total (ug/l)	1	1	1	1	1	1	20[4,9], 5[10], 50[11]	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	45.7[9], 100[11]	0	0%
Zinc, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	422[9,10], 5,000[11]	0	0%
Microcystin	0.2	10	-----	n.d.	n.d.	n.d.	-----	-----	-----
Pesticide Scan (ug/l)[D]	0.05	2					-----	-----	-----
Atrazine (ug/l)			-----	17.8	n.d.	29.6	330[9], 12[10]	0, 1	0%, 50%
Chloropyrifos (ug/l)			-----	7.4	n.d.	14.7	0.083[9], 0.041[10]	1, 1	50%, 50%

n.d. = Not detected.

(A) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C. South Dakota's dissolved oxygen criterion is 6 mg/l and Nebraska's is 5 mg/l.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (9) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (10) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (11) Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

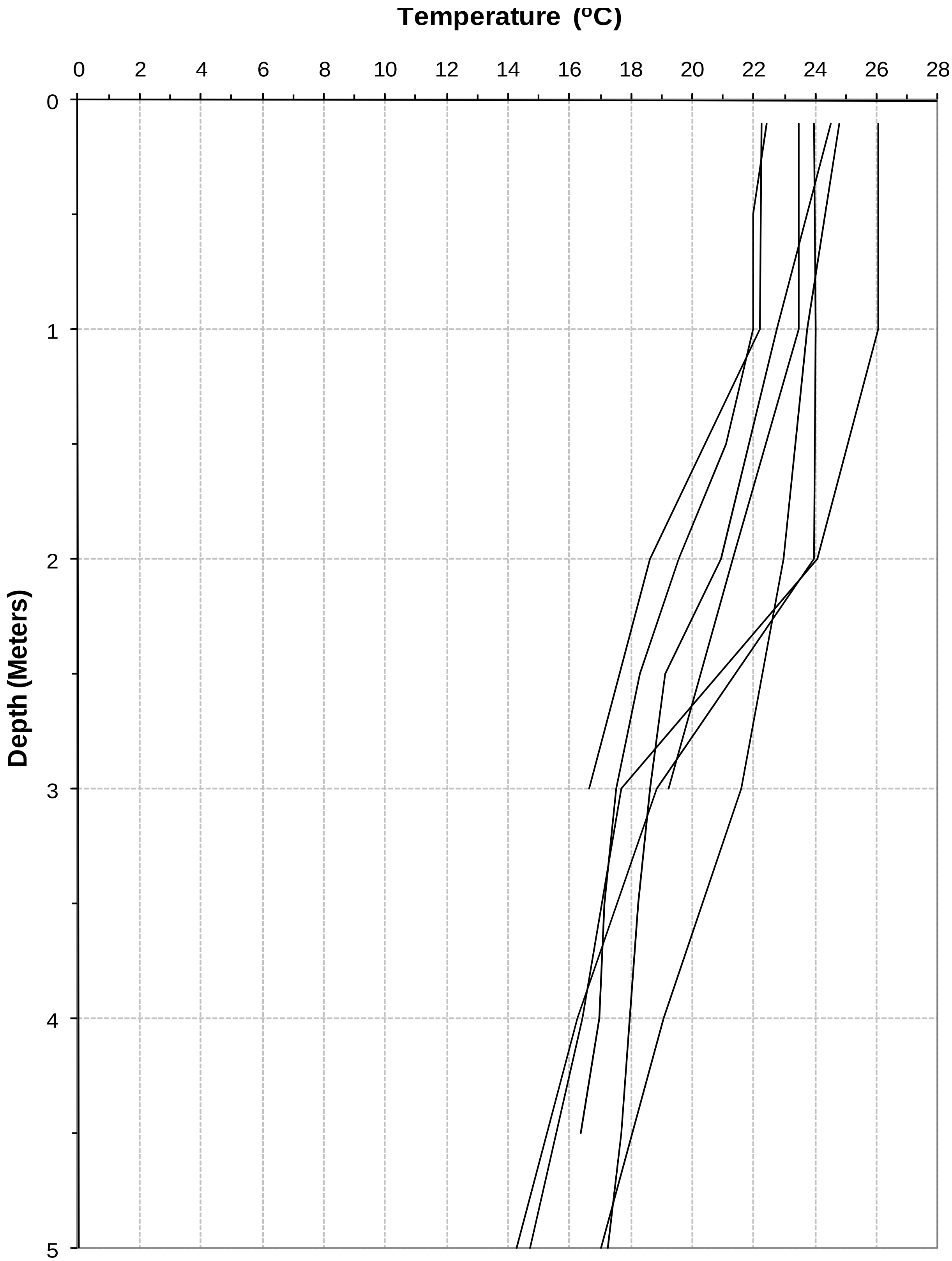


Plate 422. Temperature depth profiles for Lake Yankton generated from data collected at the deepwater ambient monitoring site during the summer months of 2002 and 2006.

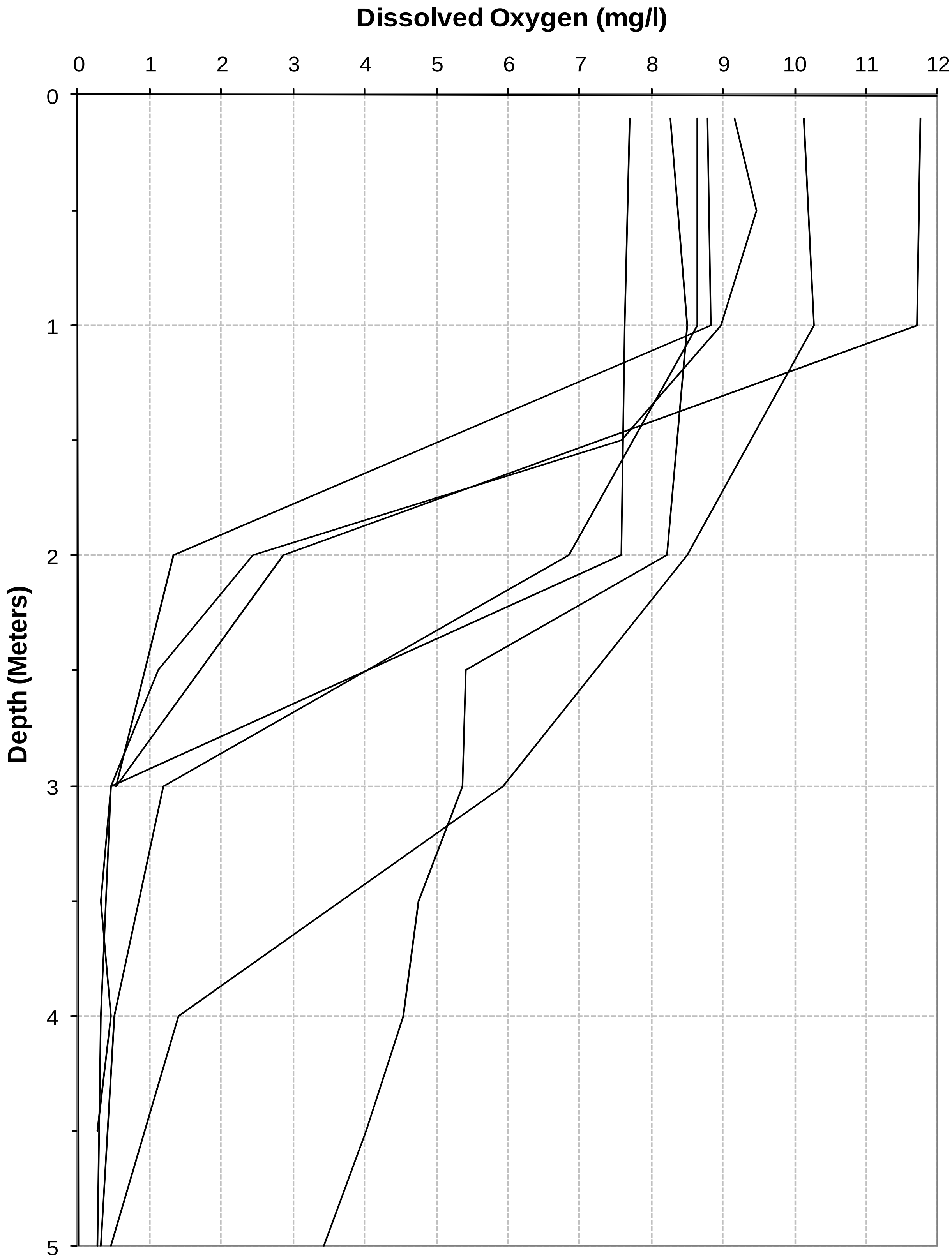


Plate 423. Dissolved oxygen depth profiles for Lake Yankton generated from data collected at the deepwater ambient monitoring site during the summer months of 2002 and 2006.

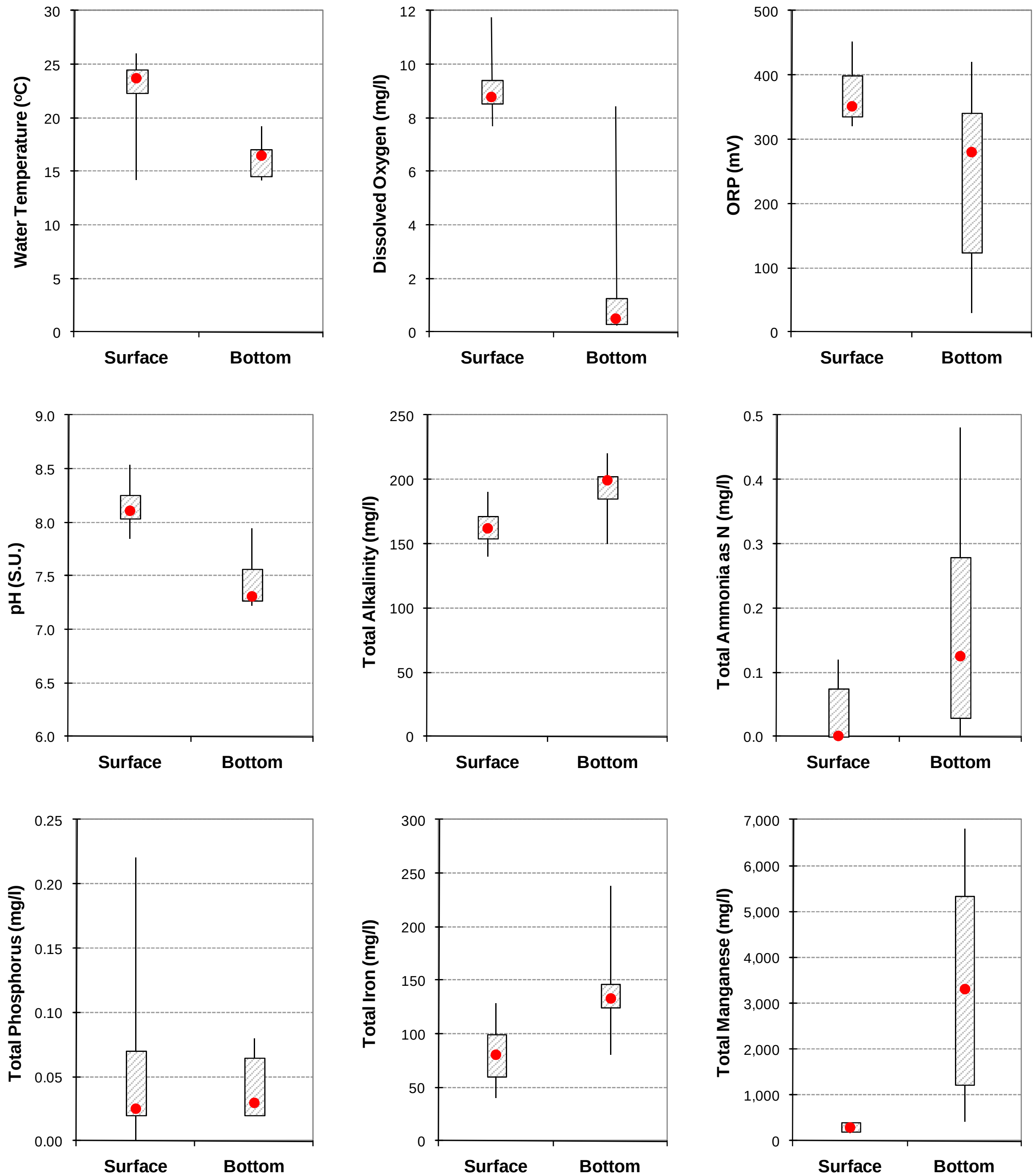


Plate 424. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total ammonia, total phosphorus, total iron, and total manganese measured in Lake Yankton at site YAKLKND1 during the summer months of 2006 and 2009.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

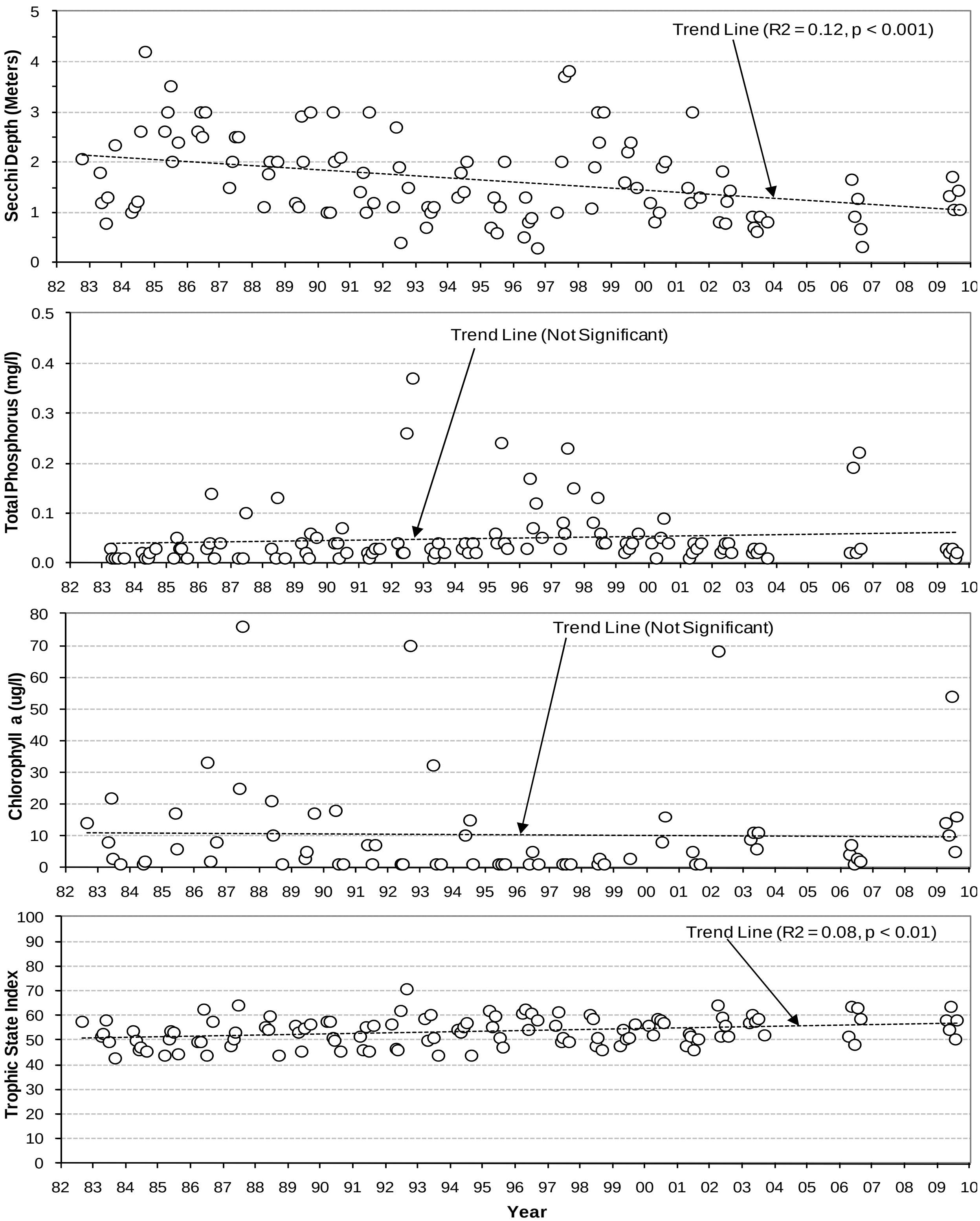


Plate 425. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Lake Yankton at the near-dam, ambient site over the 28-year period of 1982 through 2009.